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Journal of Experimental Psychology

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RAYMOND DODGE, YALE UNIVERSITY (*Monographs*)
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EDWARD S. ROBINSON, YALE UNIVERSITY (*Bulletin*)
HERBERT S. LANGFELD, PRINCETON UNIVERSITY, Business Editor

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Journal of
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VOL. XIII, No. 4 AUGUST, 1930

A DESCRIPTIVE ACCOUNT OF ODORS

BY FLORENCE WOOLSEY HAZZARD

Cornell University [1]

SETTING

Henning's classification of odors [2] represents the first psychological division of smells as such. His attempt, it is true, is open to criticism. We are inclined, however, to leave this to others and, admitting the difficulty of work with odorous stimuli, to honor a pioneer experimentalist for the impetus given to other investigators.

An adequate history of the problem undertaken by Henning may be found either in his own book [3] or in Zwaardemaker's *L'Odorat.*[4] Miss Gamble has summarized recent work,[5] and there are, in addition to her bibliographies, two sources of reference for the worker in odors which are more complete than anything we might attempt here.[6] A few points given scant mention, or none at all, by others are of particular relevance to the present problem and will be discussed.

[1] From the Psychological Laboratory of Cornell University. The research was directed by Professor L. B. Hoisington. The writer wishes to acknowledge her gratitude to him for aid and encouragement. She wishes also to extend thanks to her other observers and to Mr. William James.

[2] H. Henning, *Zeits. f. Psychol.*, 1915, 73, 151–257; 1916, 74, 305–413; 75, 177–230; 76, 1–27; *Der Geruch*, (1st ed.), 1916, (2d ed.), 1924.

[3] H. Henning, *Der Geruch* (1st ed.), 1916, 71–80; (2d ed.), 1924, 355–362.

[4] H. Zwaardemaker, *L'odorat*, 1925, 178–189.

[5] E. A. McC. Gamble, The psychology of taste and smell, status of 1929, *Psychol. Bull.*, 1929, 26, 566–569.

[6] J. H. Kenneth, *Osmics:* the science of smell, Pt. I, 1922; C. M. Louttit, *Bibliography of bibliographies on psychology*, 1900–1927, National Research Council, Washington, D. C.

We wish to point out that Henning is not alone in making erroneous statements. Macdonald [7] quotes Henning as calling thymol triplex in resemblance, although a careful reading of the original [8] will show that the odor so classified is that of thymoil or Thymöl, oil of thyme. In regard to this substance, Allen [9] says that either one of the isomeric phenols, thymol or carvacrol, is contained in thymoil, but that borneol and linalol also contribute to the odor. Isomers, though alike in composition, have not necessarily the same odor.

Von Skramlik [10] finds that localization of an odor is only possible when both an olfactory and some other receptor are affected, as the receptor for warmth or contact. His study, though undertaken from the point of view of physiology, nevertheless throws light on difficulties encountered also by psychologists.

Hermann, in his study of total experience with odors [11] is occupied particularly with affection. He compares Zwaardemaker with Henning, and concludes that the new approach of Krueger will assist in the study of the olfactory system. His own experiments take that direction. Juhász [12] believes that the foundation of the descriptive psychology of smell lies in an arrangement on a scale of *Geruchshöhe*, pitch or brightness.

In an article entitled Odeur et chimisme,[13] Zwaardemaker makes certain changes in his accepted classification. He bases these changes upon experiments on fatigue, wherein he has discovered that "les deux grandes classes importantes d'odeurs, que j'ai appelées II et III dans ma classification, sont semblables." He thus reduces the number of classes to eight, the new combination being termed 'aromatic.' Hen-

[7] M. K. Macdonald, An experimental study of Henning's system of olfactory qualities, *Amer. J. Psychol.*, 1922, 33, 551.

[8] H. Henning, *Der Geruch* (1st ed.), 299.

[9] See Allen's *Commercial Organic Analysis* (5th ed.), Vol. IV, 138.

[10] E. von Skramlik, Über die Lokalisation der Empfindungen bei den niederen Sinnen, *Zeits. f. Sinnesphysiol.*, 1925, 56, 69–140.

[11] J. Hermann, Gesamterlebnisse bei Geruchen, *Neue Psychol. Stud.*, 1926, 1, 477–506.

[12] A. Juhász, Zur Grundlegung der Geruchspsychologie, Ber. VIII *Internat. Congress of Psychol.*, Groningen, 1927, 305–309.

[13] H. Zwaardemaker, Odeur et chimisme, *Arch. neerl. de physiol.* (Arch. neerl. des sciences exactes et naturelles, Serie III, C), 1922, 6, 336 ff. (esp. 344–345).

ning [14] seems to claim more for the reduction than we can determine, particularly in the light of the recent *L'odorat*, where Zwaardemaker ignores the change and virtually translates into French the classification of his 1895 *Physiologie des Geruchs*.[15]

The chemists approach the problem from another angle. Bogert [16] reviews the classes proposed by others and says that two classes, agreeable and disagreeable, suffice for the organic chemist. He misinterprets Henning's system, stating that "there are but six elementary odors . . . and all others are made up of blends of these six in varying proportions." This he quotes from Woodworth,[17] who as a psychologist merits severe criticism for so misleading a statement.

Boring's favorable review [18] of Crocker and Henderson's work [19] appears to be over-optimistic. There is a fundamental error in their method which seems to exclude the study from the group of reliable psychological experiments. Crocker and Henderson refer the reader to Bogert for a convenient account of Henning, thus perpetuating Woodworth's error. Throughout, there is a tendency to find elements or components rather than resemblances. We believe that observers "smelling for" acid will find acid in some degree. The work, however, avoids hampering terminology, suggests further investigation, and may be of practical aid to chemists.

Dimmick [20] attributes the inconclusiveness of the previous work on olfactory qualities to the "task which has not been set for the Os, which has permitted all sorts of variable and fundamentally inadequate secondary criteria, to the insuffi-

[14] H. Henning, Psychologische Studien am Geruchssinn, *Hdbh. d. Biol. Arbeitsmeth.*, 1926, Abt. vi, Teil A, 832–833.

[15] H. Zwaardemaker, *Die Physiologie des Geruchs*, 1895, 207–238; *L'odorat*, 1925, 178–224.

[16] M. T. Bogert, The flower and the organic chemist, *J. Ind. and Eng. Chem.*, 1922, 14, 359–364.

[17] R. S. Woodworth, *Psychology*, a study of mental life, 1921, 203, 204.

[18] E. G. Boring, A new system for the classification of odors, *Amer. J. Psychol.*, 1928, 40, 345–349.

[19] E. C. Crocker and L. F. Henderson, Analysis and classification of odors, *Amer. Perfum. and Essent. Oil Rev.*, 1927, 22, 6.

[20] F. L. Dimmick, The investigation of olfactory qualities, *Psychol. Rev.*, 1927, 34, 321–335.

cient control of the presentation of the stimuli, and to the non-descriptive nature of the olfactory categories with which most of the Os have worked." In his reports "adjectives such as 'sharp,' 'smooth,' 'flat,' 'clear' occur frequently and seem to be more descriptive than class reference." He thinks it possible to describe odors in "terms which indicate the nature of the odor itself." In his experiment he obtained five descriptive categories and five usual terms in classifying odors, when his Os were under instruction to "describe."

In a preliminary study pursued at Goucher College in 1924 the writer concluded that experience conditioned by an odorous stimulus is complex in the sense that it has different aspects, any one of which in a given case may serve to characterize the total. We found appropriate—as did Dimmick—such descriptive terms as 'smooth,' 'heavy' and 'flat.' Tactual experiences were particularly prominent in our observers' reports, and in fact occurred in an inverse ratio to the amount of agreement with Henning in qualitative designation. The study is unpublished, as it reveals little else that is new.

In the confused state of olfactory classification it seems advisable to adopt a new method of study. Our preliminary study, since supported by Dimmick's work, suggested that the phenomenological method might contribute to the knowledge of the nature of odors. The descriptive terms reported might be new criteria for classification, independent of qualities or correlated with them. In the hope that an investigation under instruction to describe might bring out undiscovered facts, the present experiments were undertaken.

The Experiments

The experiments were conducted at Cornell University in 1927 and 1928, under the supervision of Professor L. B. Hoisington. Six Os took part.[21]

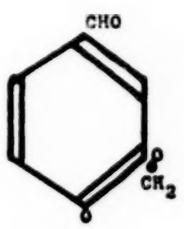
[21] The Os were Professor Hoisington (Ho); Miss Frances Wells (W), L. Freeman (F), G. Kreezer (K), O. D. Anderson (A) and the writer (Ha), graduate students in psychology. Ha acted as experimenter except when observing, when Mr. W. James kindly served in that capacity. All the Os were familiar with Henning's prism. Ho was the most highly trained observer; W, Ha and K had had much practice and F and

The fourteen odorous substances listed below were used. Numbers 6 and 8 are identical. The stimuli were presented in four series, Nos. 1–6 being given for description to Ho, Ha, W and F in two series, and Nos. 7–15, to Ho, Ha, A and K in Series III. The fourth series, carried through by Ho and Ha, included Nos. 1, 5, 10, 13, 14 and 15. We chose our stimuli from Henning's results, to represent a skeleton of his prism.

Following von Skramlik [22] we list our stimuli according to structure, as far as the structure is known. While we fail to discover chemical correlation from our results, we welcome comparison by competent chemists of our work with that of others. It may be that from some such survey of physico-chemical and psychological relations, an adequate theory may arise.

1. Heliotropin.

Piperonal, methylene ether of protocatechuic aldehyde.



Heliotropin

(Julius Schmidt, *Organic Chemistry*, Engl. ed. by H. Gordon Rule, p. 390.)

2. Geranium oil.

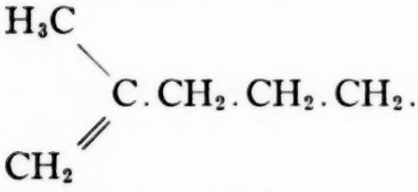
Geraniol chief constituent, with geranyl tiglate. Contains citronellol. Free acid considerable. Esters of caproic and probably of acetic, butyric, valeric acids in small quantities. Laevomenthone. Small amounts of pinene, phellandrene, amyl alcohol, linalol and paraffin. (From Allen's *Commercial Organic Analysis*, 5th ed., Vol. IV, p. 63.)

Geraniol (Allen, p. 457). Open-chain compound, monatomic primary alcohol, isomeric with linalol; $C_{10}H_{17}OH$.

A, little previous observation. Ha had taken an undergraduate major and graduate minor in chemistry, hence was familiar with odorous substances as well as with olfactory description. All the Os were normal as regards the olfactory range.

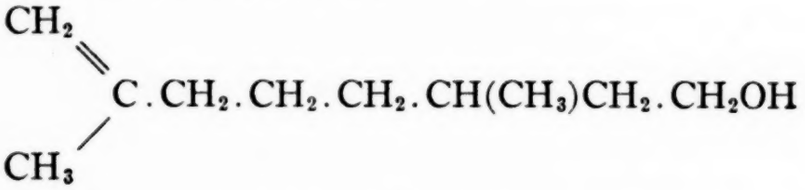
[22] E. von Skramlik, *Zeits. f. Sinnesphysiol.*, 1925, 56, 91 ff.

$(CH_3)_2C{:}CH.CH_2.CH_2.C(CH_3){:}CH.CH_2OH$ (Probable)



(Possible)

Citronellol (Allen, p. 463.)

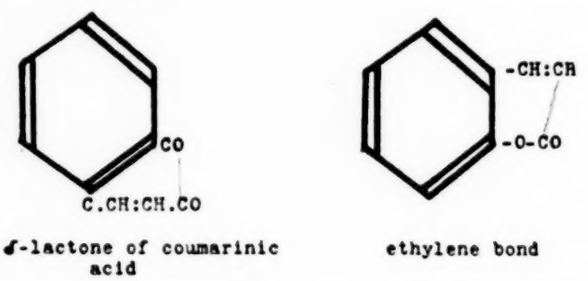


Differs from geraniol by 2H atoms.

3. Tonka bean.

Coumarin, predominating constituent. See 4. (Allen, p. 582.)

4. Coumarin. $C_9H_6O_2$.



δ-lactone of coumarinic acid

ethylene bond

Coumarin

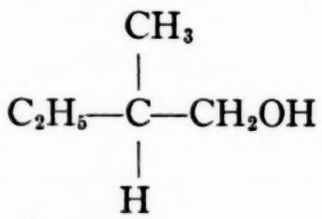
δ-lactone of coumarinic acid (Allen, Vol. IV, p. 581.)

Ethylene bond (Cohen, *Organic Chemistry*, Pt. II, p. 146.)

5. Tar.

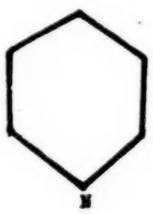
Composition varies with origin. Largely hydrocarbons, but oxygenized and nitrogenized substances sometimes present in considerable proportion. (From Allen, Vol. III, p. 32.)

6. Amyl alcohol.



(Cohen, Pt. II, p. 182.)

7. Carbon disulfide. CS_2.
   Odor from impurity. Possibly H_2S.
8. See 6.
9. Pyridine.

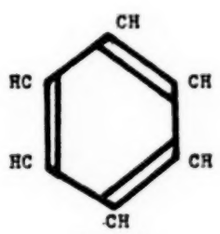


Pyridine

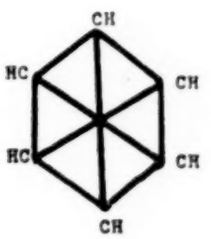
(Allen, Vol. V, p. 270.)

Ring nitrogen compound.

10. Hydrogen sulfide. H_2S.
11. Benzol.



Kekulé

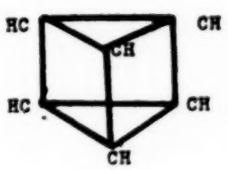


Claus, diagonal

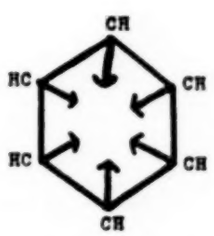
Benzol

Kekulé (from Cohen, p. 424.)

Claus, diagonal (from Cohen, p. 437.)



Ladenburg, prism



Armstrong-Bayer, centric

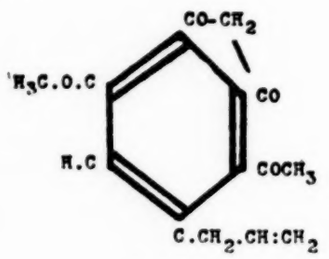
Ladenburg, prism (Cohen, p. 438.)

Armstrong-Bayer, centric (Cohen, p. 450.)

Also space and dynamic formulæ.

12. Apiol.
    Allyl-dimethoxydihydroxybenzenemethylene ether.
    Parsley camphor, occurs in oil of parsley.

Commercial apiol—large proportion of true apiol. (Allen, Vol. IV, pp. 505–507).



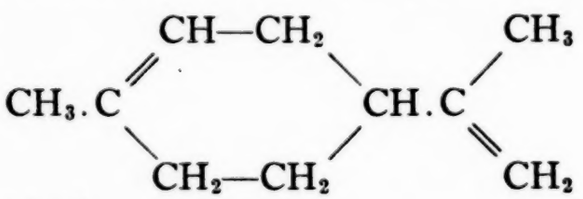
Apiol

13. Sweet orange oil.

90 percent dextrolimonene.

Small amounts dextrolinalol, nonylic acid, decylic alcohol, dextroterpineol, normal decyclic aldehyde, esters of butyric acid and immediately higher homologues, an ester of caprylic acid, methyl anthranilate or orthoamino-benzoate. (Allen, Vol. IV, p. 86.)

Limonene (dipentene) (Allen, p. 432). $C_{10}H_{16}$.



14. Cedarwood oil.

Tricyclic sesquiterpene principal constituent. $C_{15}H_{24}$. Cedrene.

Cedrol, $C_{15}H_{26}O$ sometimes present. Not essential.

Cedrenol, pseudocedrol. (From Allen, Vol. IV, pp. 36, 451.)

15. Cinnamon oil (cinnamon bark oil).

Cinnamic aldehyde largest constituent; but much of perfume value from non-aldehydic portion.

Eugenol, $C_{10}H_{12}O_2$; a phenol. Cf. high percent in clove oil. (Allen, Vol. IV, p. 43.)

Methyl-amyl ketone, benzaldehyde, pinene, phellandrene, cymene, nonylaldehyde, cumic aldehyde, hydrocinnamic aldehyde, linalol, linalyl esters, caryophyllene present. (Allen, p. 32.)

Cinnamic aldehyde (Allen, Vol. III, p. 437).

$$C_6H_5.CH{:}CH.CHO.$$

Instructions. At the beginning of the experiment E gave the following preliminary instructions, "In this experiment you are to close your eyes. During the actual smelling you are to inhale through the nose and exhale through the mouth at a normal rate and depth."

Specific instructions for the several series were as follows:

Series I. "Breathe normally, and maintain a passive attitude. You will be presented with an odor. Describe your experience." This was altered, after a few trials, to read "describe the course of your experience."

Series II, III. As Ser. I, when altered.

Series IV. As Ser. II, except for the addition, "noting particularly the course from the time specificity is reached."

Procedure. The stimuli were presented in uniform dark glass bottles with mouths an inch wide. These bottles were kept stoppered (with glass stoppers unless the chemical was very volatile, when cork was used), and widely separated on an open table when not in use. By adjusting the amount of chemical, the intensities were equalized as far as possible according to preliminary work by Ha. The observers were asked to note any differences of intensity which interfered with their descriptions. As none were reported, the intensities were kept constant by Ha's weekly inspection and, if necessary, by refilling from larger bottles. The same precautions were taken with the large bottles as with the small ones, to avoid absorption of foreign odor.

During the experiment, a light current of air passed through the room from open window to open window. O sat in front of a gray screen which concealed the bottles and E, who sat at right angles to O, in such a position that with her left hand she could hold the bottle under O's nose. The typed instructions were posted in a conspicuous place where O read them before presentations.

The odors were presented in haphazard order. E removed the stopper, gave the 'ready-now' signal, and held the open

bottle eight inches from O's nose for the time appropriate to the series, as determined by a stop-watch. She removed the bottle and gave the 'now' signal, stoppered the bottle and recorded O's report. The time of exposure was 3 seconds, or one normal inspiration, except in Ser. II, when it was lengthened to 5 sec or 2 inspirations.[23]

In Ser. I, Ho gave 15 reports for each odor, Ha, 15, W, 27 and F, 13. In Ser. II, Ho gave 6, Ha, 5, W, 5 and F, 7. In Ser. III, Ho, Ha and A reported 6 times, and K 5 times. Ser. IV included 4 reports from Ho and 6 from Ha. Our criterion for the number of reports was the satisfaction of the observer, and constancy of results. After the first series, which included practice, the number is fairly constant.

The total number of reports for each odor, hence, is as follows: 1 and 5, 103; 6–8, 116; 7, 9, 11, 12, 23; 10, 13, 14, 15, 33; and 2, 3, 4, 93. The uneven division is characteristic of this essentially descriptive study.

Results

Olfactory qualities. Table I lists the qualities reported by four observers, with Macdonald's designations of Henning's classes: Fragrant (F), Ethereal or fruity (E), Spicy (S), Resinous (R), Putrid (P) and Burned (B). A did not report quality, and K infrequently used the terms 'fragrant' and 'putrid' in somewhat the sense of pleasant and unpleasant, not on a parallel with our other reports.

In an effort more closely to approximate our terminology with that in the modality of vision, we have adopted a useful schema. A, bA, BA, AB, aB, B represents a continuum from A to B, in analogy to the series in color, as: blue, greenish blue, green blue, blue green, bluish green, green. The fragrant-spicy series thus becomes: F, sF, SF, FS, fS, S, which reads: fragrant, spicy-like fragrant, spicy fragrant, fragrant spicy, fragrant-like spicy, spicy.

Under this terminology, Findley's prism surface[24] is

[23] We favor the 3 sec exposure. The second wave was usually like the first, and the longer time seemed fatiguing for the observer, who tended to slight the end in the report.

[24] A. E. Findley, Further studies of Henning's system of olfactory qualities, *Amer. J. Psychol.*, 1924, 35, 441.

altered to admit thirty-six shades of difference instead of her twenty-five.

The scheme still omits certain combinations of minor resemblances (such as fsRE). These can, however, be placed in approximate relation to the nearby qualities, thereby increasing the possibilities of the scheme. The complete prism includes three such faces and two triangular sections to represent triple resemblances.

We have taken the liberty of translating, as far as possible, the results of others into our terms, in our Table I. We agree with Miss Findley [23] in regard to the errors in Dimmick's Table II, and derive our conclusions from his Table I.[25]

A comparison of the designations reveals no glaring inconsistencies in Ser. I and Ser. II except for odor 6 (amyl alcohol). This was therefore repeated as number 8 in Ser. III, where we discover that our most highly trained O agrees with Henning. For purposes of comparison, it is unfortunate that A and K, who had not had previous experience with the odor, did not report quality in Ser. III. We find, under textural designations and in the answers to questions quoted later, a definite likeness between fruity and putrid. Confusion between them might easily occur if the observers were set by the series to take the experience as 'fruity-fragrant' or as 'putrid-burned-fruity.' This seems to be a case of imaginal overlay.[26] We shall go further into the problem of attitude, which played an important part in the study.

We wish to warn the reader against a quantitative interpretation of these results. As our instructions did not emphasize quality, the observers did not always include this aspect in their reports. The numbers are rough and do not admit of a percentage comparison with others. To obtain them, we simply counted the number of times a quality-name was reported, assigning the value 1 to an unequivocal report, .5 to a resemblance reported either as slight or doubtful, and .3 to one both slight and doubtful. While our method may be

[25] F. L. Dimmick, A note on Henning's smell series, *Amer. J. Psychol.*, 1922, 33, 424, 425.

[26] G. K. Adams, An experimental study of memory color and related phenomena, *Amer. J. Psychol.*, 1923, 34, 390, 391.

TABLE I

No.	Odor	Obs.	F	E	S	R	P	B	Qual.	Final	Others
1	Heliotropin	Ho	17.5	4.5	1.8	1.5	3.3	2.5	peF	esF	H—SF
		Ha	22		2				F		B—F
		F	10.5	2.5	5	1			esF		Z—3c
		W	29.5	2	1.5				F		
		Tot.	79.5	9	10.3	2.5	3.3	2.5	esF		
2	Geranium oil	Ho	10.8	9.3	10.5	5.3	.8	2.5	reSF	rseF	H—F
		Ha	18.3	7.5	6.3				seF		D—ESRF
		F	7.5	3	1.8	5	1	.5	eRF		Z—2d
		W	24.5	3					eF		
		Tot.	61.1	22.8	18.6	10.3	1.8	3	rseF		
3	Tonka bean	Ho	20.3	6	3	.5	.5		seF	sF	H—SF
		Ha	1.8		1.8			.5	F		D—SF
		F	4.5		11.8				fS		F—erFS
		W	26		9.5				sF		Z—3c
		Tot.	68.8	6	26.1	.5	.5	.5	sF		
4	Coumarin	Ho	20.5	4.3	2.3		.8	.3	seF	sF	H—SF
		Ha	23		1.5		.5	1	F		D—sEF
		F	4.5	1.3	12	.5			fS		B—sEF
		W	32.5		7.5				sF		Z—3c
		Tot.	80.5	5.6	23.3	.5	1.3	1.3	sF		
5	Tar	Ho	1	.5	1	5		8.5	RB	sRB	H—B
		Ha	2.5		.5	13		15	fRB		D—B
		F		1	1	1	3	11	pB		Z—6b
		W	1.3		5	22		10.3	sbR		
		Tot.	4.8	1.5	7.5	41	3	44.8	sRB		
6	Amyl alcohol	Ho	7.8	15.3	2.3	5.8	7	.5	rpfE	pFE	H—BP
		Ha	5.3	10.3			5	6.5	pfbE		Z—6b
		F	6	12	.3				fE		
		W	28	17.5					EF		
		Tot.	47.1	55.1	2.6	5.8	12	7	pFE		
7	Carbon disulfide	Ho				.5	5	1.5	bP	bP	H—P
		Ha					5.5	2.5	bP		
		Tot.				.5	10.5	4	bP		
8	Amyl alcohol	Ho		1.8	.5	3	5	4.5	erBP	rBEP	H—BP
		Ha	1	5		1	2.5	2	bpE		Z—6b
		Tot.	1	6.8	.5	4	7.5	6.5	rBEP		
9	Pyridine	Ho		.3		.5	1.5	4	pB	pB	H—B
		Ha	1					3	fB		D—bP
		Tot.	1	.3		.5	1.5	7	pB		F—PB
											Z—6a
10	Hydrogen disulfide	Ho		.3		.5	10	1	P	P	H—P
		Ha	1				13		P		Z—5
		Tot.	1	.3		.5	23	1	P		
11	Benzol	Ho		1		3		3.3	eRB	erB	H—fRB
		Ha	1.5	2	.5	.3	.8	3.3	feB		D—ebpR
		Tot.	1.5	3	.5	3.3	.8	6.6	erB		F—prB
											Z—6b
12	Apiol	Ho	.3	1	.5	.5	1		srEP	eFPS	H—FBSP
		Ha	3	1	4		2.5		epFS		D—srB
		Tot.	3.3	2	4.5	.5	3.5		eFPS		Z—2c
13	Orange oil	Ho	2.8	9	2.3	2.5			srfE	srfE	H—E
		Ha	1.5	7					fE		D&F—fE
		Tot.	4.3	16	2.3	2.5			srfE		Z—2d
14	Cedarwood	Ho		.3	1.5	4.5	2.5	5.5	spRB	pfbR	H—R
		Ha	5.3			5.5			FR		D—sR
		Tot.	5.3	.3	1.5	10	2.5	5.5	pfbR		Z—2d
15	Cinnamon oil	Ho	8.5	3	5.8	2	1	1	reSF	reFS	H—S
		Ha	8		11				FS		D—S
		Tot.	16.5	3	16.8	2	1	1	reFS		Z—2b

H—Henning, Geruch, 1916, S. 81; 1924, S. 363.
D—Dimmick, 1922, p. 424.
F—Findley, p. 445.
B—Bentley, p. 148.
Z—Zwaardemaker, 1895, 233–235; 1924, 190–218.

questioned, we advance the argument that the obvious qualities will most probably be mentioned most often. Of more significance than our total is the report of either Ho or Ha, both trained observers who observed throughout the experiment.

It may be noted that other observers have shown the same tendency as ours toward naming more resemblances than Henning reports. We more closely approximate their results than Henning's, and indeed our results show more 'scatter' than do they in the cases of 5 (tar), 13 (orange oil), 14 (cedar-wood oil), and 15 (cinnamon oil).

It is fitting that every O agreed in the characterization of Nos. 3 and 4 as identical, since reference to the chemistry of these stimuli shows that the odorous component of 3 is 4 itself. We chose our stimuli from Henning without this knowledge. The choice offered an accidental check on the careful work of our observers.

In general, our results fit into Henning's odor prism. The exceptions are numbers 14, 12 and 5, which should be placed in the interior.

In addition to Henning's terms, other qualitative designations infrequently occur: 1—musty; 2—oily, soapy, acid, musty and aromatic; 5—tarry; 6—acetic, rancid; 12—earthy and 14—woody, camphorous. The equivalents of the terms musty, rancid and earthy are found in Hermann's study.[27]

Ha differentiated between two fruitys, namely mellow and clear. She defined her terms thus;

(Ser. III, trial 2, odor 13) clear fruity as lemony is fruity. (II, 3, 6) Mellow, heavy or rich fruity like bananas. (III, 4, 6) like pears or bananas.

Woody was placed by this observer between resinous and fragrant. (III, 3, 14.)

The close resemblance of qualities on the FESR face was noted. It may be that Zwaardemaker's 'aromatic' class has psychological support.

F (I, 13, 3) Trouble separating fragrant and spicy. Difficult to say where one ends and the other begins. Ha (III, 2, 14) Fragrance shades into resinous very easily. F (I, 15, 2) This piney quality somewhat resembles spicy, but seems to be marked off from that, and it is also marked off from the fragrant. Essentially, I believe, all three may be wrought out of the same stuff.

[27] J. Hermann, *Neue Psychol. Stud.*, 1926, 1, 503.

Fragrant was likened to sweet by several observers.

Ho (I, 13, 3) Sweetish-fragrant, a lot like sweet in taste. W (I, 2, 4) The sweet wasn't taste. It was a sweetish odor. F (I, 12, 6) That sweetness is very different from the fragrant kind, more like fruity.

In a certain sense, the term sweet was used to describe odor quality.

K (III, 1, 15) The quality has something that I call sweetish. W (I, 2, 6) I want to call it a sweetish smell, but I'm not sure what I mean by that. F (I, 9, 4) Sweet and spicy.

Sour, another taste term, was used in this modality.

Ho (III, 8, 7) Sourish-fruity and isn't taste; but sour is the only word I can find. (III, 2, 12) Sour . . . as smell, not taste. K (III, 5, 9) Seemed a blend of slight fragrance with something sour-like, and those seemed to be the smell qualities.

Other modalities and affection. Qualities in other modalities than olfactory were frequently reported. Table II shows the frequency of tactual terms, tastes and the few affective terms which revealed the complexity of experience with odorous stimuli. We include in the table a comparison with von Skramlik wherever possible. Bearing in mind that a larger number of reports were taken on Nos. 1–6, we compare the members of each group among themselves and discover that of the three in group I with a small number of tactual reports (1, 3, 4) von Skramlik does not mention No. 3, and suggests 1 and 4 as stimuli for odor without localization. On the contrary, No. 9, conspicuously our most 'tactual' member of group II, he designates as '*Stichschmerz.*'

We did not discover among our meager gustatory reports a sweet taste with No. 7. No. 9 verifies von Skramlik in this respect. So far as we have used his stimuli, we are in agreement with von Skramlik's conclusions.[28] Our reports show the tendency toward localization coincident with tactual complexity which he finds, *e.g.*,

Ho (III, 3, 11) That was definitely more cutaneous than odor. . . . The whole experience localized definitely in the nose. (III, 3, 9) Definite nose localization. Seemed to throw me into it. . . . Cutaneous before odor quality. (III, 9, 11) I can't get the smell and the cutaneous thing apart. . . . Much alike at the first moment. Afterward, became definitely localized in the nose.

Ha (III, 2, 9) Clearly localized . . . odor and cutaneous experience. (IV, 4, 15) It filled up my nose and was more cutaneous than odorous.

[28] E. von Skramlik, *Zeits. f. Sinnesphysiol.*, 1925, 56, 122.

TABLE II

TACTUAL, TASTE AND AFFECTIVE QUALITIES

	Group I						Group II								
Quality	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Prick	1			1		2	2		1			1			4
Tactual		3						1	1			1		1	
Pressure	3	1			1										
Cutaneous		1	1		1	1	4	4	9	3	6		1	1	2
Sting			3	3	6	6									
Light pres.		2	2	2	2	6									
Pungent		1			1										
Bright pres.					1										
Dull pres.						1									
Sharp pres.						1									
Strain										1					
Pucker	1														
Biting				1											
Sore			1												
Tingle						1									
Organic		1													
Sickish		3													
Cool									1						
Temperature				1											
Total	5	12	7	8	12	18	6	5	12	4	6	2	1	2	6
Sweet	24		15			1			2						
Sour		1				1									
Bitter									2						
Taste					1										
Pleasant	1	1		1	1	2									
Unpleasant		1			2	2									

v. Skramlik.
1—no localization.
4—no localization.
7—sweet taste.
9—sting, smart, taste.

W (I, 7, 6) Touch experience entered into it, light pressure within the nostrils and at the very end light pressure over the surface of the tongue. (III, 2, 6) The perceptualized smell was a fairly definitely localized bit of experience. . . . There came a slight stingy, pressury experience in the nostrils.

In spite of the many instances of apparently inseparable qualities in the two modalities, we believe that with sufficient training, observers can pick out the components. Several instances of such observation occurred, as,

Ha (III, 6, 7) Cutaneous stuff localized and odor not. Ho (I, 14, 6) There was a cutaneous factor there. It came in a little later than the smell, and when it came, it didn't seem to offer great difficulties in abstracting out.

The experiences, on the whole, were not taken affectively. This aspect drops out entirely with the advent of the third series, and does not, under the conditions of this experiment,

correlate with stimulus. We can neither affirm nor deny the relation that Henning and Findley have determined.[29]

Descriptive terms. Having ascertained to what extent our work supports that of Henning and subsequent investigators, we turn to the bulk of our reports. Early in the study it was obvious that our observers were 'describing' in terms of texture, volume, brightness, extent and temporal course the nature of the experience itself. We attempted to discover whether this nature correlated with quality or any other aspect previously used in classification. We chose our remaining stimuli to fill out the several classes now known. It was at this point also that we changed our instructions to read. "Describe the course of your experience." All the Os but W were describing a course, and except for mentioning the sequence, W was conforming to the others. After the change in instruction, she also included the temporal aspect.

Henning's classes were, in the main, accepted as appropriate to the textural criteria. The four observers who reported quality consistently correlated the quality and descriptive terms. We have grouped in Table III those terms specifically applied to an odor in connection with the aspect named. A comparison with Table I will show that a few apparently foreign designations, such as (Ho, odor 1) putrid occurred infrequently, and are discounted in the final qualities in Table I, although they appear here.

In addition to the terms listed, we find a few cases of textural report without mention of quality. These plainly indicate a quality which, in all cases agrees with the designation given the odor, and are therefore omitted as unessential. We include in our table the textural terms of A and K. We have divided them according to designations by the observers as 'this aspect and that,' 'two parts' and the like. A and K gave us so little data that we cannot compare their reports with those of the more practised observers. A comparison of terms shows excellent agreement with each other, and fair agreement with the other observers. The main difference is in fineness of distinction.

[29] A. E. Findley, *Amer. J. Psychol.*, 1924, 35, 444.

TABLE III

DESCRIPTIVE TERMS

	1	2	3	4	5	6
Ho	*Fragrant* Loose Bright Lively Fine Soft Motile Filmy Uniform Fluffy Delicate Light *Fruity* Dense Bulky Compact Translucent Small Mellow Smooth Thick *Putrid* Dead Dark	*Fragrant* Loose Extensive Bright Lively Motile Fine Light Soft Fluffy Filmy *Resinous* Thin Coarse *Fruity* Dense Bulky Compact Volumic Translucent Flooded Dull Heavy Stifling *Spicy* Coarse *Putrid* Inert	*Fragrant* Loose Bright Extensive Lively Delicate Soft Quick Motile Filmy Diffuse Fine Fluffy Mild *Fruity* Dense Deep Heavy Thick Congealed Bulky Dull *Spicy* Coarse *Putrid* Dark Inert	*Fragrant* Loose Extensive Bright Fine Lively Volumic Filmy Delicate Diffuse Labile Uniform Spread Motile Thin Soft Fluffy *Fruity* Dense Congealed Bulky Heavy Deep Dull Smooth *Spicy* Coarse Sharp Rough *Putrid* Dead Inert	*Resinous* Loose Thin Diffuse Spread Extensive Surface-like Granular *Burned* Dense Bulky Rough Compact Heavy Inert Dead Dark Coarse Deep Dull *Fragrant* Fine Uniform Smooth Lively Light Mild Filmy	*Fruity* Dense Bulky Smooth Heavy Translucent Compact Small *Fragrant* Bright Lively Extensive Motile Loose Fine Atomistic Soft *Putrid* Dead Inert Dull Dark *Resinous* Sharp Coarse Diffuse Thin
Ha	*Fragrant* Soft Light Fine Fluffy Airy Expansive Easy Thin Filmy Diffuse *Spicy* Permeating Clear Insistent	*Fragrant* Light Soft Misty Airy Fine Lifting Spread Quick Fluffy Expansive Gentle Buoyant *Fruity* Clear Heavy Translucent Filling Thick Held down Full	*Fragrant* Light Fine Soft Diffuse Misty Deep Spread Lively Fluffy Cottony Gentle Expansive Filmy Even Airy Bright Buoyant *Burned* Thick Held down	*Fragrant* Light Fine Diffuse Soft Loose Misty Fluffy Lively Thin Cottony Gentle Buoyant Spread Quick Free Filling Voluminous *Spicy* Keen	*Burned* Dull Flat Gritty Heavy Compact Constricted Tight Sharp Keen Inert Substantial Granulated Harsh *Resinous* Diffuse Rough Loose Fine Light	*Fruity* Full Rich Deep Clear Smooth Stuffy Loaded Filling Thick Mellow Held down *Burned* Flat Rough Tight Coarse Harsh Sharp Keen

TABLE III.—*Continued*

	1	2	3	4	5	6
Ha		*Fruity* Penetrable Rich Cloudy *Spicy* Insistent Brilliant Vivacious Penetrating			*Fragrant* Soft Lively Misty Quick Expansive Clear Lifting Transparent Buoyant Tingling Voluminous	*Fragrant* Soft Diffuse Light Misty Thin Spread Fluffy Filmy Lively Tingling Bright Fine Expansive *Putrid* Dull Heavy
W	*Fragrant* Light Small Soft Airy Fine Smooth Motile Loose Not dense Flat Thin Diffuse *Spicy* Dense Sharp Keen Tang-y	*Fragrant* Light Soft Smooth Small Fine Airy *Fruity* Dense Volumic Big Heavy Rich	*Fragrant* Light Soft Airy Motile Fine *Spicy* Sharp Keen Lively Tang-y Dense	*Spicy* Sharp Keen Dense Fluid Big Filmy Bright Rich Penetrating *Fragrant* Small Light Soft Airy Fine Lively Motile Loose Not dense Smooth Thin Not voluminous	*Spicy* Keen Lively Loose Fine Light *Resinous* Volumic Big Tang-y Penetrating Wire-like Dense *Burned* Flat	*Fragrant* Light Soft Small Motile Loose Thin Sharp Airy Smooth Penetrating *Fruity* Dense Rich Volumic Heavy Thick Big
F	*Fragrant* Fine Diffuse Smooth Light *Fruity* Heavy Full *Spicy* Sharp	*Fragrant* Light Airy Fine Diffuse *Resinous* Sharp *Fruity* Full Heavy Bulky Thick Big	*Spicy* Lively Sharp Penetrating *Fragrant* Smooth Light	*Spicy* Lively Sharp *Fragrant* Fine Light Diffuse Atomistic Smooth	*Burned* Rough Heavy Harsh Hard Sharp Lively Granular Insistent *Putrid* Inert Full Voluminous Rich Dead	*Fruity* Full Heavy Thick Smooth *Fragrant* Diffuse Light Even Soft Loose Voluminous Sharp

TABLE III.—*Continued*

	7	8	9	10	11	12
Ho	*Putrid* Inert Loose Extended Bulky Smooth Soft Dead Dense *Burned* Rough Flat Volumic Compact	*Putrid* Smooth Dead Bulky Extended Loose Soft Dull *Fruity* Translucent *Burned* Flat Granular *Resinous* Lively Filmy	*Burned* Granular Rough Motile Flat Surfacy *Putrid* Smooth Bulky Extended Loose Diffuse	*Putrid* Inert Volumic Dense Thick Diffuse Extended Dull Loose Drab Soft Dead *Burned* Compact Rough Granular Flat	*Burned* Massive Loose Granular *Resinous* Diffuse Dry Clean *Fruity* Dense Murky	*Putrid* Dense Smooth Loose Massive Dead Dull Murky *Fruity* Translucent Bulky *Spicy* Bright
Ha	*Putrid* Heavy Inert Dense Jelly-like Full Lump *Burned* Harsh Dull Hard Rough	*Fruity* Full Mellow Loaded Yielding Light *Putrid* Soft Heavy *Burned* Harsh Hard Rough	*Burned* Rough Harsh Dull Heavy Gritty Dense	*Putrid* Jelly-like Heavy Inert Lump Dull Thick Viscous Tough Rubbery Dead Constricted Translucent Liquid-like Smooth Firm	*Burned* Rough Heavy Harsh Gritty Condensed *Fruity* Jelly-like Full Mellow Clear *Fragrant* Light Rounding Soft Vaporous Diffuse	*Spicy* Rough Light Misty Fine *Fragrant* Soft Filmy *Fruity* Clear
A	Dark Dense Soft Smooth Volumic Heavy Dark Loose Bulky Massive	Tight Firm Soft Fine Bright Lively Smooth	Soft Dense Smooth Volumic Heavy Dull Sluggish Firm Tight Sharp Lively Bright Thin Rough Sparkling	Dense Dull Tight Volumic Sluggish Massive Heavy Loose Soft Smooth Spread Voluminous	Soft Smooth Bright Loose Filmy Spread Wiry Tight Dense Bulky	Smooth Soft Bright Lively Clean

TABLE III.—*Continued*

	7	8	9	10	11	12
K	Loose Heavy Turgid Dense Thick Volumic Soft Smooth Penetrable Clear	Thick Soft Dense Turgid Light Airy Smooth Buoyant Bright	Dense Heavy Thick Turgid Soft Loose Light Sharp Thin	Heavy Turgid Dense Thick Soft Sharp Thin Loose	Soft Loose Clear Smooth Thick Turgid Dense	Clear Buoyant Soft Light Smooth Heavy Dense Thick

	13	14	15		13	14	15
Ho	*Fruity* Translucent Clear Smooth Bulky *Fragrant* Loose Soft Delicate *Resinous* Granular Rough Flat Extended *Spicy* Active Brilliant Pungent	*Burned* Coarse Concen- trated Flat Rough *Resinous* Granular Extended Loose *Putrid* Smooth Soft Drab Dense Bulky	*Fragrant* Soft Diffuse Delicate Fine Motile Light *Spicy* Loose Lively Extended Sparkle Spray Rough Granular *Fruity* Bulky Clear Heavy Dense	Ha	*Fruity* Clear Liquid-like Light Bunched Translucent Full *Fragrant* Voluminous Soft	*Resinous* Rough Light Fine Misty Surfacy Clear Particles Lively Expansive *Fragrant* Soft Smooth Buoyant Oily Deep	*Spicy* Keen Airy Particles Sparkling Clear Set Hard *Fragrant* Soft Light Loose Fluff Misty Fine Expansive
A	Bright Sharp Smooth Soft Tight Bulky Sluggish Massive	Soft Smooth Loose Bright Lively Sluggish Bulky Tight Dead Heavy	Lively Sparkling Sharp Bright Clean Rough Hard Tight Smooth Dense	K	Sharp Thin Light Clear Soft Smooth Dense Thick Heavy Turgid	Smooth Clear Airy Light Thin	Sharp Light Clear Smooth Heavy Hard

There is a striking similarity in the terms descriptive of one quality as assigned by any one observer throughout the experiments. Furthermore, all the observers agree closely in their descriptions of the qualities. In Table IV we have arranged the terms common to two or more observers, grouping similar designations. Most of them refer to

texture, falling into six continua: loose-tight, light-heavy, smooth-rough, soft-hard, thin-thick, sharp-dull. The other four descriptive continua, bright-dull, lively-inert, surfacy-deep, and small-large are included under the term texture, although they do not refer to the structure or texture proper. These ten categories were, for all the observers, criteria for classification. For Ho the extent or volume was more significant than for the other observers, who noted extent at times but assigned it little importance.

Table IV presents the typical description of each 'corner

TABLE IV

QUALITY AND TEXTURE

Frag.	Clear E	Mellow E	Spicy	Recs.	Put.	Burn.
Loose	Trans-	Full	Brilliant	Rough	Inert	Rough
Diffuse	lucent	Rich	Sparkling	Particles	Dead	Granular
Thin	Clear	Loaded	Bright	Light	Dull	Harsh
Free	Liquid-	Flooded	Airy	Fine	Drab	Gritty
Vaporous	like	Mellow	Vivacious	Misty	Sluggish	Coarse
Bright	Bright	Dense	Active	Lively	Dark	Turgid
Lively	Smooth	Cloudy	Lively	Loose	Heavy	Hard
Motile	Bulky	Turgid	Penetrat-	Surfacy	Bulky	Sharp
Quick	Bunched	Deep	ing	Expansive	Lump	Keen
Labile		Bulky	Sharp		Full	Flat
Light		Compact	Keen		Jelly-like	Tight
Airy		Firm	Spray		Massive	Dense
Buoyant		Heavy	Particles		Thick	Dull
Lifting		Volumic	Rough		Volumic	Heavy
Fine		Stuffy	Granular		Smooth	Surfacy
Misty		Stifling	Loose		Soft	Motile
Soft		Smooth	Extended		Dense	
Filmy		Soft			Viscous	
Fluffy		Thick			Tough	
Cottony		Dull			Rubbery	
Delicate					Firm	
Gentle					Turgid	
Mild						
Smooth						
Even						
Uniform						
Expansive						
Spread						
Extensive						
Volumic						

odor' or turning point in Henning's system. While one odor is rarely, *e.g.*, purely spicy or purely fragrant, it may have textural and qualitative resemblance to both spicy and fragrant. In such a case, the description would combine those found under the fragrant and spicy columns.

Resemblance in texture correlates with resemblance in quality, *i.e.*, fragrant resembles fruity, and the textures are alike in smoothness and brightness but different in bulk and weight. Clear fruity closely resembles fragrant, while mellow fruity is more like the heavy putrid.

From our data we can arrange the qualities on the ten descriptive continua. Not all ten are represented for every quality, resinous showing a particular paucity of terms. Our reports allow the following summary:

Loose-tight. Fragrant, spicy, resinous, clear fruity, mellow fruity, putrid, burned.
Light-heavy. Fragrant, spicy, resinous, clear fruity, mellow fruity, putrid, burned.
Smooth-rough. Clear fruity, mellow fruity, putrid, fragrant, resinous, burned spicy.
Soft-hard. Fragrant, mellow fruity, putrid, spicy, burned.
Thin-thick. Fragrant, clear fruity, burned, mellow fruity, putrid.
Sharp-dull. Spicy, fragrant, burned, mellow fruity, putrid.
Bright-dull. Spicy, fragrant, clear fruity, mellow fruity, burned, putrid.
Lively-inert. Spicy, fragrant, resinous, burned, mellow fruity, putrid.
Surfacy-deep. Resinous, burned, mellow fruity, putrid, fragrant.
Small-large. Mellow fruity, clear fruity, fragrant, resinous, spicy, putrid.

To substantiate our statements we quote from the reports of all the observers:

Ho (I, 12, 6) The heterogeneity is not of quality . . . but in terms of extent, of texture, of density which is probably texture, of brightness, liveness, inertness. It's in those ways that experience patterns a heterogeneous whole. Ha (II, 7, 4) My standard for quality seems textural. I don't say that quality itself is textural, but it is as if quality is there over and above texture, but the standard with which I compare afterward is more prominently texture than it is quality. (II, 6, 6) It was texture that gave t the resemblance. F (I, 9, 4) The more I observe in this problem, the more ready am, I to accept quality as the patterning of the other attributes. A (III, 5, 11) Between the last odor and this one I'm sure that one practical difference is one of texture. K (III, 2, 14) Intrinsic to the quality is the texture. (III, 5, 11) The texture is the essential part of odors, more than quality. The smell can be pure texture as to constitution. At other times there's a framework suffused with some other quality that may have a texture of its own. The texture then is relatively non-prominent.

Fragrant: Ho (II, 9, 1) If that experience had been just a little looser, softer, in a sense smoother, it would have been straight fragrant. (I, 2, 3) Fragrant. Fairly extended, very indefinite. Quite loose, brightish, somewhat lively, quick. Of fair depth. Ha (I, 4, 2) Something like fragrant. It got finer, mistier, more gentle as this resemblance came in. (I, 11, 3) Fairly light, very fine, soft, cottony fluff of odor. It was fragrant—not verbally—almost pure fragrant. It was uniform except that it expanded and grew somewhat larger, never very large. W (I, 3, 3) Flowery odor. It was soft and light, not very volumic. I don't know why I call it flowery, because it

isn't the smell of any particular flower. (II, 2, 1) I use flowery as a sort of class name. I don't know how to give the shades of difference. The experience as a whole was slightly denser, less loose, less lively than most of the flowery experiences. F (I, 12, 4) Globular character of the fragrant odor. There's something intrinsically finer about the fragrant odor. Comes minute, finely divided, but clear and clean. As a total, this odor is smooth. (I, 13, 3) Toward the fragrant. Experience is less intensive more diffuse, more deftly colored and perhaps a trifle smoother than that which is spicy. The quality in the fragrance seems to be alive, has movement about it, as contrasted with the inert experiences that seem to fall about the putrid.

Fruity: Ho (I, 12, 1) Translucent bulkiness of fruity. (IV, 1, 13) Clear, smooth, bulky fruitiness. Ha (II, 7, 6) Fruity, the heavy kind. I think if the corner of fruity is taken to be a clear fruity, like oil of lemon, that this would certainly be between that and putrid. It has the richness of putrid without its inertness, however. Textural resemblance is what I note. Resemblance always seems underlying, textural, and quality to be just specific characterization of the texture. (III, 4, 13) A fine, light but not airy, rather constricted odor which was clear fruity, not mellow. W (I, 11, 6) What I have called fruitiness seems to be not really quality but merely the relative thickness, density and richness of the experience as compared with most flowery experiences. (I, 3, 6) Fruity-like and flowery-like. It was a rather big, voluminous experience. It was richer, more dense than most of the flowery experiences. F (I, 18, 2) A little like fruity. The fullness of the fruity. (II, 7, 1) Something of the heaviness of fruity. The heaviness is not of putrid. The richness, fullness or heaviness. It is as rich and as heavy as putrid. It lacks the inertness of putrid.

Spicy: Ho (III, 8, 15) A certain amount of sparkle of spicy. The liveness of spicy is . . . like streaks that tend, as it were, to streak beyond the odor. (IV, 4, 13) Like spicy, a fairly loose but active, brilliant-like, pungent experience that had poorly defined extent. Ha (III, 4, 15) The texture was light, scattered in particles, keen, clear-like, like spicy in its keenness. (III, 6, 15) Rather soft but with a keenness, a sparkle, that kept the odor from being sheer fragrant. This part I called spicy afterward. W (I, 5, 3) Spicy resemblance. It was sharp and fine. (II, 6, 3) Spicy resemblance. The experience was lively, light, fine in texture. Not quite as smooth as the flowery experiences. There was something like points of lively, dense experience in the total. F (I, 11, 3) The somewhat sharp, staccato-like impression which spiciness gives to the qualitative pattern. (II, 1, 4) A little rough, probably spicy.

Resinous: Ho (III, 10, 14) Somewhere around the resinous end. Fairly extended, rather inert, coarse, bulky mass. (III, 4, 14) Quite indefinite in boundary. Smooth and slightly bulky-like. Ha (III, 4, 14) A buoyant odor, not as large as fragrant, but still expansive, finely divided and again not as fine as fragrant. Between fragrant and burned somewhere in fineness, I think. Somewhere near resinous. (III, 4, 12) Took on a roughness and almost at once a lightness, so it had both the characteristic roughness of burned and characteristic lightness of fragrance, but later I called it resinous fragrant. Resinous does have some of that roughness, and this had not really the heaviness of burned. Somehow the fragrant-burned always changes to fragrant-resinous, as if fragrant and burned were incompatible, burned being too heavy to combine with fragrant. W (II, 6, 5) Resinous. Very loose, fine, soft bit of experience. (II, 5, 5) Small, rather compact, yet lively. It was heavier, denser than most of the flowery experiences. F (I, 19, 2) Piney or resinous in quality. A trifle too rough for spicy. Not rough enough for scorched, though.

Putrid: Ho (II, 6, 6) Mostly putrid. Fairly limited—not very sharply, though.

Kind of massive focus, which was fairly dead, inert, not very dense, fairly loose. (IV, 3, 10) Putrid. Distinctly massive, compact for just a moment. Ha (III, 5, 10) Quality sheerly putrid. A thick, viscous, heavy, jelly-like mass. (III, 6, 7) The odor was putrid, but not as soft a putrid as some. Rather a hard, harsh one that has a slight resemblance to burned. F (I, 15, 3) The putrid and perhaps the other two (fruity and tarry) focus on a background more dense, heavy and dead-like. There's not the aliveness to putrid that there is to spicy, fragrant.

Burned: Ho (III, 8, 14) Mostly burned. Definite in extent, wide-spread and I think granular. Fairly inert, not very live and active. Rather drab-like—I suppose just that it isn't bright and lively. (III, 6, 9) Burned. Fairly extended, tended toward flatness as smell, fairly inert. There was rather a dense-like aspect to it, though the thing as a total was generally loose. Ha (I, 1, 5) Heavy, rather dull, tightening odor. Close in, as if constricted. (III, 4, 9) Odor was heavier than the cutaneous part, but both were harsh, and hard to separate. F (I, 18, 5) Harder, more ragged than the putrid ones. It has characteristics common with putrid—heavy and limited in extent. I think it must be scorched that gives it its roughness. (I, 13, 5) A tarry, scorched thing. It's thick and heavy. W (I, 15, 5) That was a fairly volumic, fairly thick, dense experience. The quality was something between scorched and resinous. It was a rather lively experience, sharp, tang-y, not as soft or as smooth as flowery experiences. (I, 6, 5) Fairly big, fairly dense, thick smell experience with specific quality, between resinous and scorched.

Temporal course. All the observers but K, who made few observations, noted a temporal course whose stages we designate pre-qualitative, qualitative or specific, and post-qualitative. The term 'pre-qualitative' is not necessarily genetic. In the pre-qualitative stage the quality of the odor was suggested. Out of this grew the qualitative stage, where the quality was made specific. The Os had a tendency to be satisfied with the naming of the quality and to omit or make brief report of the post-qualitative stage. Series III, designed to make our reports complete, revealed nothing of particular significance in this dying out. The three stages were not discrete, but showed even development. We have separated them for convenience. We quote reports in full:

Ho (I, 10, 2) It was mostly fruity. Maybe fragrant. The experience again in its very initial moment was not smell at all and yet I have the feel that if it could have been cut off somehow there, I'd have known that it would be smell. Of course this initial moment was very brief. Still definitely, clearly there. There is a vague, general sort of attitude, I think, to smell. There is no specific set. I mean I'm not absolutely clean of any set. There is some there. The experience goes on changing, still gradually for a while, and becomes smell pretty quickly, and pretty quickly the general qualitative nature is there, although not verbally. Near the end there was a shift to the quality, a set that meant 'What is the quality?' and quality leaped out rather quickly, with a tendency toward verbalization. What I really had was just weak little pressures in the throat and each of very short duration, a succession of them.

In the first part, after it became smell, however, there was a fairly limited, quite dense, bulky experience with something a little looser, livelier about the margin and then when it was quality it was a little more extended, probably, and a little more bulky, volumic mass. Was almost as if I felt the bulk of it in the mouth or throat somewhere. Very, very obscure; the dominant thing was quality, with what I call tendency to verbalization—these little pressures.

Ho (III, 1, 12) The quality becomes definitely a smell quality only when I recognize the sort of quality that it is. I mean that certainly there came first of all a change of experience that I should not designate as qualitative, a change of a small area in experience, becoming a little more intensive, a little denser, a little more tridimensional-like. In other words, a part of experience seemed to stand forth as something that could be looked at, fixated. I'm inclined to say there was something there, a qualitative change, but I couldn't say for sure it was qualitative, until I recognized it as belonging to a qualitative class. It wasn't definitely qualitative at first and then the quality classified. It became specifically qualitative with the classification, as it were. Then for a while it remained fairly uniform, as a fairly definite, rather elongated mass of experience. That went out fairly abruptly with a shift to observation.

Ho (IV, 5, 13) That attained to full detail, full richness in stages. In the first stage it was mostly like spicy, fairly loose but active, brilliant-like. Somewhat pungent experience that had poorly defined extent. Then it became more like a familiar smell, *i.e.* the smell of a familiar substance. But now it was very much better defined in extent, much bulkier, somewhat fruity as well as resinous. Still retained a suggestion of spiciness but all that in textural rather than qualitative terms. Just that kind of an object. Never identified. Remained fairly uniform for some while. Weakened a little. Became softened up, loosened up, more indefinite in experience. Something less tangible, graspable, palpable but with a little increase in the strength of the smelling, came back a bit. This showed the usual two stages in going out—a weakening a good deal like the one in the middle and then a sudden complete disappearance which coincided with the end of inspiration.

Ha (I, 11, 3) At first just a slight change, an expanding of the stream of experience. It was slightly lighter, then soon after that a rather broad, I should say—though not spatially speaking—flow of fairly light, very fine, soft, cottony fluff of odor. It was fragrant, not verbally, almost pure fragrant, was uniform except that it expanded and grew somewhat larger, never very large.

Ha (III, 5, 13) The stages in that experience were waiting for odor, waiting for fragrant odor, when the pressuriness assumed a lightness that it had not had before, then fragrant-fruity odor which changed to a clear fruity. The stages were not discrete, but melted into one another. The difference between fragrant stage and the fragrant-fruity was in a sort of liquifying of the first misty fragrant. Quality and texture were there at the same time. Quality seemed to be a grouping of textural aspects. It was incipiently verbal, and in that form overhung the end of the experience.

Ha (IV, 3, 14) After quality there was a dwindling in extent of the experience, and it was just undifferentiated odor for a moment, when it had a soft, rather light texture, and was odor only because there had been odor there. This lasted a very brief time and except for a bit of kinaesthetic strain connected with observing, the experience was gone.

W (II, 5, 1) The first thing I caught was some slight shift in pressury strain pattern. A shift of attitude, which meant that smell experience was coming. Either with that change or immediately following it, there came a rather small extent of very

loose, soft pressure, which was referred out there somewhere, in the general direction of the nose. The pressure didn't seem to belong to me. It was just out there. Almost at once this pressure began to take on smell quality. It became less like pressure and more like a sweetish, flowery smell. But the quality wasn't specific. It wasn't a flowery odor at this moment, but I somehow knew that the experience was going to be flowery. The smell experience increased slightly in volume and in density, became a more compact bit of experience, set off more sharply against the pressury-strain background. With these changes, the odor took on specific flowery quality. It was a very light, fine, loose, lively experience. The quality was definitely flowery at first. A moment later there was a little qualitative shift and spicy resemblance came into experience. It was still a simple quality although it had two resemblances. There was no noticeable change after that for some time, until the beginning of expiration. With that, the smell experience suddenly decreased in volume and density, diffused out, became weaker and weaker until it was finally gone. The quality remained unchanged.

W (I, 18, 6) At first just a pressury strain pattern which referred out there and meant expectancy for smell experience. Then came a tiny bit of soft, smooth, sweetish smell experience. It had no definite localization, no definite quality. As it came in, the pressury strain pattern loosened up and faded into the background of experience. The smell stuff remained at that stage for a moment or two, then rather suddenly it became a big mass of dense, rich smell experience with definite quality. It was fairly clearly defined as a total. The quality had a flowery resemblance but also a second resemblance which I call fruity. A moment later the experience loosened up a bit, became a little less volumic, and then very quickly decreased in volume and faded out of experience.

F (II, 2, 2) The hardening of the pressure strain background was rather rapid. But the focal part of the experience did not immediately impinge on the hardened background. There was a moment of time when the thing out there existed extent-wise with little else. And then this extent seemed to become clearer Details of it now came out—its texture, its surface. Intensity wasn't exactly lacking in the background. It becomes very dominant, however, in the focus. It gave a hint of sharpness and I accepted the quality, spicy which came from it. Later in the experience, as the odor persisted, a new aspect of it became attentionally dominant, to the exclusion of the intensive pattern which meant spicy. It was really like the redistribution of the stuff there with a new dominance. The thing was not only spicy, but quality-wise tended toward fragrant.

A (III, 3, 8) The odor first of all very definitely develops, *i.e.*, I notice the thing as odor long before there's anything specific. Something happens to this bare odor stuff: it seems to be this sort of thing. I can't say anything first about this odor stuff except that it's darkish, fairly soft, uncontoured. It's spread. It's an unstable sort of thing. It's somehow out of this stuff that a more particular liveliness, brightness of tint, more definite contour, a finer texture comes. All of these things specify the odor. This core is fairly dense, a cleancut thing, rather firm, but somehow a softish sort of firmness. I probably mean by firmness, simply cleanness of this stuff, its definiteness, its more or less preciseness. And yet the stuff that makes up this sort of firmness is qualitatively soft, as I said.

A (III, 3, 13) The experience as it rounds out definitely into odor is not very dense, fairly loose. A thin sort of thing. Yet it has spread, not a definitely contoured spread. It seems to become weaker somehow toward the outer edges. The principal density of the thing is somehow in the center or core. The core seems to come later

than the fringe. It is this core which makes the odor become a specific kind of odor. It is the density of the stuff and volume which directs, as it were, the core sort of stuff toward specificity. Somehow this stuff is compared with other odors, not specifically with particular kinds or labelled odors, but is more or less laid alongside them as to brightness. I don't know whether this brightness is a visual thing or not. The stuff is very lightish, somehow, not in the sense of fairly keen sparklingness. It is fairly lively, which somehow seems to be bound up with its sparklingness.

Dimmick, in regard to his odors, remarks, "Some odors have a definite temporal course." He may refer to adaptation, or to the course we find here. While we cannot say, "All odors have a definite temporal course," we can state that, under the conditions of our experiment, all of our odors manifested that phenomenon.

Attitude of the observer. The relation between quality and texture had not been declared, although all the observers had reported a consistent correlation. To determine this relation, if possible, we asked a number of questions of our two most experienced observers. In addition, questions were put to W at the end of the second series.

The answers bear out the correlation shown in Table IV. W expresses the relation between quality and texture as 'always associated with.' Ha says, "I do not know whether to say odor quality has specific texture or is specific texture." Only Ho definitely explains the relation, "I think texture plus . . . qualitative set may be quality."

We quote the questions and answers in full. They summarize much of the foregoing material and express the deductions of the observers.

Questions asked HO and HA

1. (*a*) Can you make a general statement as to the nature of specific odor? (*b*) Do you classify odors, and if so on what basis? (*c*) Have you any schema to represent the classification? (*d*) Is the classification original?

2. Have you any comments as to how specificity of odor comes?

3. (To Ho only.) In your classification, is there any relation between texture and quality? If so, what relation?

Answers, Ho

1. (*a*) No odor is in the very first instant specific. It becomes specific with a shift to a qualitative attitude, perhaps quality-perceptive attitude. I don't mean the qualitative attitude is not perceptive. With that it becomes qualitatively specific and specific as odor, but when I shift to this qualitative attitude it practically always is to look for some particular quality, a confirming act rather than an act of discovery of certain aspects, which means, I suppose, that I take specific odor to mean one to which I can assign a specific name, usually quality, in rare instances, object.

So far as the actual basis for this qualitative specificity is concerned, the odor really becomes specific but not nameably so, in terms of what one might call texture. This may involve extent somewhat but I think primarily it might go under texture. As I look for a specific odor, I look for it in terms of quality. I ignore this very brief pre-qualitative moment. I'm strongly impressed with the fact that the qualitative shift is not a general one, is not quality in general but in particular. It must have its antecedent moments involved.

(*b*) Yes, although I don't try to work out complete schemas of classification. At various times I use at least three different bases. First, they may be classified in terms of pleasant-unpleasant. In the second place, I classify odors in terms of the Henning prism. In the third place, I classify them on what I call a textural basis. In my reports I haven't been quite consistent in my use of the word texture. It includes density, which is probably the primary aspect of texture, and it also includes motility or liveness, and includes the constitution of the odor—structure may be a better word—whether it's fine-grained or coarse-grained, or whether granular, or stringy (pretty near); composition. I'm not sure that it does include anything else. Sometimes I do a fourth thing—classification by objects, that's somehow different from the first thing.

I'm not very likely to classify an odor unless there's somehow a demand for it. Habitually I don't. Which one of the four things one does is a function of the situation, I

suppose. It would be hard to give a judgment. If one does, it would be that the textural classification is psychologically more adequate than the second.

(*c*) I think my answer is "no," but I'd like to make this statement: As far as I've pondered, I've worked along this line, of trying to get two lines or three to represent the textural aspects and then getting these lines in such a relation that I can show the degree of these aspects in any case. One line should represent liveness-inertness, one the degree of coarseness, and another density, and then I should see if I could put them together to show the combination of particular aspects in any particular odor. I haven't the thing done at all.

(*d*) The only one that approaches originality is the third. 3. I'm very strongly inclined to think there is a fairly definite relation. I don't believe that texture is quality, that is, texture alone. I think texture plus whatever happens in this what I call qualitative set may be quality. Of course the qualitative set is probably determined by the texture, and that's why one can say there's a very intimate relation. Texture determines the set, and texture and set give quality. Furthermore, as a fact of observation, I think one fairly soon begins to notice that there is always a similarity of texture when you have on successive occasions similar quality or *vice-versa*, so that empirically there is close relation. Of course empirically nothing as to the nature of the relation—whether causal or identical.

A concrete illustration. A fragrant odor is always loose, very fine-grained, delicate, labile rather than progressive, live, brightish, soft in a way, gentle sort of experience. Fruitys are much denser, more compact, more concentrated, something like smooth, practically no grain at all. Density is carried to the point of solidity, practically no motility, liveness, but there is a kind of progressiveness. Still it isn't dead, inert. The fruitys in general are of less extent, more sharply confined. The putrids again are loose, not quite so loose as the fragrant, nor quite so delicately soft. Just a hint of granularity. Quite inert, dead. A receptive experience.

The scorched-burned I don't feel I know quite so much about. More granular than the putrids, and much more than spicy or fruity. They haven't much of anything like liveness. The granularity is sort of a pseudo-appearance of liveness. They're not airy, but dense, more than the putrids. The resinous—a little like fruity, that is, tend to become a little denser, harder, still granular and fairly coarse. Sometimes it's almost like a lower, denser part and an upper part. The spicys are fairly loose again, not quite so soft as the fragrants. They're pretty indefinite in extent but not so much granular as rayed. Simply, these aspects of experience are coarser so that the motility takes on a different appearance, more like shootings, dartings. Each of these rays or darts is more concentrated, more dense than fragrant. The thing as a whole doesn't give an appearance of density. Quite bright, on the whole.

Answers, Ha

1. (*a*) Specific odor, I think, has texture and the texture varies with the quality of the odor. There are in particular certain classes into which they seem to be grouped, and the quality names which I have given are general terms indicating these classes. I have found, in general, the following designations and their meanings to be: 1—fragrant—soft, fugacious (upward and outward expanding), buoyant mist. There are degrees of lightness which characterize the sheerness of the fragrance. I have called these: airy, buoyant, light, slightly held down and the like. Fragrant odor is bright but not sparkling. The sheer fragrant is sometimes brilliant. There are degrees of liveliness corresponding to those of brightness. Fragrant is diffuse, like cutaneous cool.

2. Spicy. Typical spicy is sparkling, light and somehow distributed in what I call particles. There are points of it. Not as big a thing as fragrant, but fairly voluminous. It's the sparkle of it which particularly differentiates it from fragrant to which it bears a resemblance otherwise.

3. Resinous. Fairly lively, like spicy in that it is distributed, but a softer, duller thing than spicy. A bit rough, grained, fairly expansive and light.

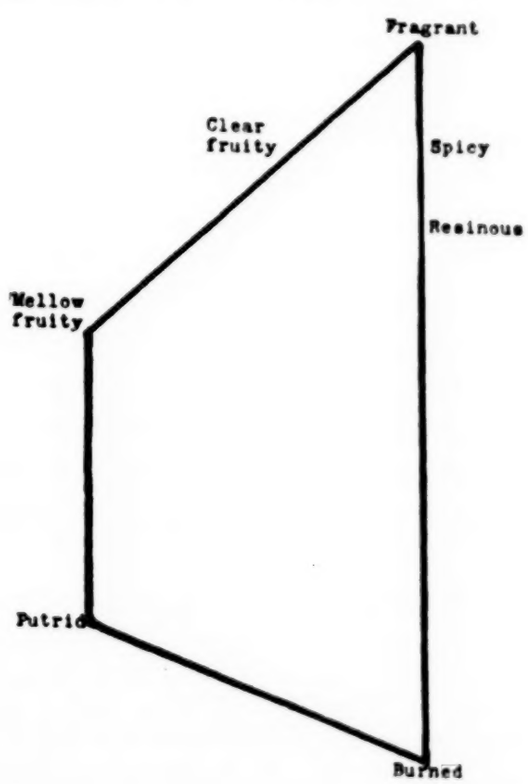
4. Burned. Burned is heavier than resinous, and lacks the liveliness of resinous; a dull, dark thing, but scarcely inert; gritty in its roughness, heavy, rather constricted.

5. Putrid. This is a lump, between opaque and transparent (using visual terms). A very full, tightly packed experience, clumped together. This is heavy.

6. Mellow fruity. This is filled, soft, jelly-like. Much like putrid, and yet not as heavy as putrid. A bit more smell-throughable than putrid, and softer than putrid.

7. Clear fruity. A keener, lighter experience than mellow, a bigger thing than mellow, more fugacious like fragrant, liquid-like in its clearness.

(*c* and *d*) This is Henning's classification, modified to include two fruitys. They are utterly different. The figure only represents resemblance of typical odors. I cannot make



it tridimensional. I should need more dimensions to expand it properly. There is, hence, no significance attached to the surface between the lines. Length of lines represents degree of similarity.

2. There seems to be a definite course which is typical of these experiences. After the signal there is waiting, and a bodily set of holding somehow, just a motionless set. And there is a slight bit of localization around the nose that makes that set for an odor. During this time experience is undifferentiated except for that indefinite localization. It is pressury, a neutral thing. Soon after this first stage there is sheer textural specificity which varies only in having an upward and outward direction, or an inward-downward, a lightness or a heaviness, a softness or hardness, smoothness or roughness, all this in varying degree. It changes more sharply than did the first stage. Suddenly there is odor, *that* odor. It seldom reaches a name, but very often a group which is incipiently named, that is, recognized with a bodily drop of tension, so well that afterward I name it without hesitancy. At this qualitative stage, when specificity is at the maximum attained, the texture of the experience is very prominent. It could not be that quality and have any different texture. I do not mean that all fragrants, for instance, are texturally alike, but one particular fragrant is of one particular texture, while in general all fragrants have similar texture, and so on with other classes which I have named. I do not know whether to say odor quality has specific texture or is specific texture. I'm inclined to say the latter. At times the texture of the experience changes also. Qualitative resemblances seem to be different aspects of the same textural experience. These aspects are neither temporal nor spatial, but simply experienced, pre-temporal and pre-spatial.

Question asked W: Can you characterize these experiences? Answer:

A number of the odors in the group were either flowery or resembled flowery quality. Their floweriness consisted in a lightness, a motility, a sweetishness. The fruity resemblance which I have mentioned is something thicker, richer, heavier than flowery experience. The spicy resemblance is sharp, tang-y, rather concentrated, dense. The experience which I described as resembling tar and resin seems to be qualitatively very different from the rest. Question 2: Is there any relation that you can define when you say "consisted in," "is"?

Answer: I've used the terms flowery, spicy, fruity, etc., as class names, indicating classes of olfactory qualities. The other descriptive terms might be called secondary

attributes. They are other ways in which experience varies. For instance, when I say 'flowery quality consists in sweetishness, lightness,' etc., I mean simply that the sweetishness, lightness, etc. are always associated with the flowery quality.

By instruction we tried to rule out shift in attitude. The task and the instruction to take a 'passive attitude' were together interpreted as instruction to take 'the attitude to smell.' In general, this set, supplemented by that to observe, was followed during the experiments. All the Os followed a course of attitudinal shifts which paralleled changes in experience. Ha, in particular, reported varying bodily pressures which are obviously such shifts. Ho's reports furnish us particular information about the changes.

The usual attitudes during the course of the experience were smell, qualitative or perceptive, occasionally verbal, and finality or release. At times (as in the first report below) a naive passivity prevented all odor experience. Infrequently, the objective attitude was taken, and at these times experience was very complex, and the odor scarcely had quality but was 'the odor of a thing.' This attitude was most common with odor 5 (tar) and indeed proved a barrier to ready classification. Rarely, defence and acceptance preceded the qualitative stage.

As indicated in the answers to questions and reported frequently throughout the experiments, Ho differentiated individual 'searching sets' for the various qualities which were the outcome of the pre-qualitative stage. The temporal relation between stages, then, as well as the quality-texture relation lies in the attitude or bodily background. The whole experience is thus integrated and is dependent not only on stimulus but on the experiencing individual.

That the attitude of the observer may overcome the predisposing stimulus influence is shown by the confusion in regard to the quality of amyl alcohol. The set may be called the most important factor in odor experience. As the observer looks at now one, now another aspect of the experience, the characteristics of that aspect are dominant. A fragrant-fruity odor may be now light, now heavy, as the resemblance to fragrant or fruity is observed. Here, then, is the explanation for the seeming incompatibility of terms.

Perusal of the reports quoted under 'Temporal course' will reveal evidence of the attitudinal factor. In addition we quote:

Ho (II, 4, 6) The separate resemblances, so far as noted, came as the result of a special attitude for each one. I think my initial attitude was naively passive. Like common sense, with a certain set to smell. Passive in the sense that it wasn't a set to smell any particular thing. I couldn't smell right off.

Ho (I, 14, 4) There certainly is a different attitude for observation; there are different ways of taking it. Somehow the set is more intimate with the odor. Sort of an acceptance of the odor. Again in this, that aspect of experience is one I can with a fair degree of certainty refer to the bodily pressure although it doesn't stand apart, discrete.

Ho (IV, 3, 14) I really tried to be passive, just sit and not smell. I didn't get anything. Then presently I began to smell. The passive attitude was a passive smelling.

Ho (II, 5, 5) Just the first instant it was tarry, an indefinite sort of experience. But it quickly became tar, objectified. One of the few I have had objective reference for. The whole bodily set was definite and fixed.

Ho (I, 14, 2) When a shift from experience as a focus or background to a quality, which made up practically the whole of experience, came, there was a very positive shift in the observational set. It's that same kind of thing that I've described as the shift from bare, unattached outthere-ness to the sort of intimate, personal belonging, without of course a specific ego reference. The first set may be described as the attitude of cold, impersonal observation. The second set is characterized as the set to appreciate the odor. No, the word 'appreciate' connotes affection too much. The set doesn't carry affective reference. The set to live the odor—just as bad. I don't know what that is. The bodily pressure tension in the second case was a little less strain-like, a little less definite, more diffuse. In the first set, the bodily experience stands definitely as background. In the second it's given along with the odor.

Ha (I, 13, 3) It was just a set for odor, a waiting for odor. But at the same time it was a set for a fragrant odor, a set for a softness. The quality definitely followed the set and, when it came, was focal against the set as a background.

Summary

Fourteen odorous stimuli, representing Henning's six classes and a number of intermediates, were presented, under controlled conditions, to six observers. The instruction was to describe the course of experience.

The olfactory qualities reported and those in other modalities were tabulated and compared with former classifications. The descriptive terms and their correlative qualities were likewise tabulated. Reports to show the temporal course of odor experience were collected, and the attitudes revealed in them were classified.

Conclusions

1. The qualities assigned by Henning and checked by other investigators were verified for twelve of our odors. Our observers tended to name more resemblances than Henning assigns. With three exceptions the qualities can be placed on his smell prism.

Our one glaring exception to the naming of quality was amyl alcohol, which was reported differently in two series. We attribute this to likeness of fruity and putrid, and to the influence of 'set' for fruitys and fragrants in one series and for putrids and burneds in the other.

3. Tactual qualities appeared frequently with certain odors, and most often in connection with localization.

4. Affective experiences were rare.

5. The terms descriptive of texture fell into ten continua. Combinations of the terms correlated with qualitative designations.

6. The course of experience included the pre-qualitative, qualitative or specific and post-qualitative stages. Our 'pre' is a temporal term.

7. Odor experience was found to be dependent on the attitude of the observer. The intimate relation between texture and quality depends on a specific set, particularized by the pre-qualitative stage of the experience.

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READING AND LEGIBILITY OF CHINESE CHARACTERS: II

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READING HALF-CHARACTERS

Studies of western languages. The problem of the relative importance of partial exposure of a word or line was, according to Huey,[2] first noticed by Javal, who indeed sensed most of the problems in reading. From watching the course of an after-image along the line as he read and for other reasons, Javal was of the opinion that the advantage for perception in the upper half of the line is due to the fact that the eye's fixation point moves along between the middle and top of the small letters. Huey does not, however, "consider his experiments final on this point" (although they perhaps *are*, so far as they go) and tries to point out, in addition, that words are better differentiated in the upper than in the lower part, as is shown by Messmer's count of 238 letters projecting above the line to 32 letters projecting below.[3] Huey also points out that we habitually find most meaning in the upper parts of objects because we ourselves are so placed and so oriented as to bring this about. He demonstrated this convincingly by testing the comparative difficulty of reading two mutilated passages of exactly the same type by cutting them into upper and lower halves.

Huey reports also on the considerably greater importance for perception of the first half of a word than the latter half.

[1] The writer is greatly indebted to Professor Walter R. Miles for general supervision and constant encouragement. Thanks are due to my sixteen subjects. The expenses of the research have been largely born by the Thomas Welton Stanford Fund for Psychological Research. This paper is the second of a series on reading and legibility of Chinese characters. The first appeared in this JOURNAL, 1929, 12, 156–177.

[2] E. B. Huey, *The psychology and pedagogy of reading*, 1908, pp. 98–99.

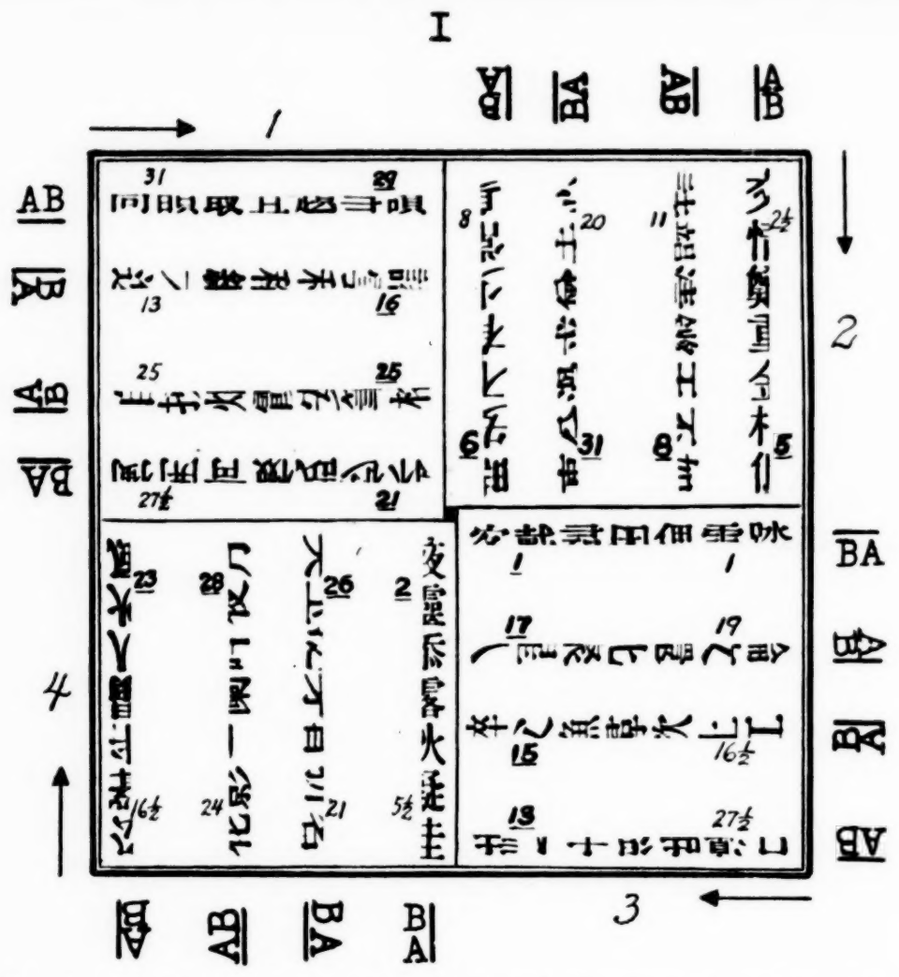
[3] O. Messmer, Zur Psychologie des Lesens bei Kinder und Erwachsenen, *Arch. f. d. g. Psychol.*, 1903, 2, 190–298.

He noticed that he finds himself much more conscious of the beginning of words than of their other parts. He prepared two identical passages, in the one case he carefully removed the first half of each word and in the other the second half. "It was found that more words were made out, and in less time, when the first halves were read than when the latter halves alone remained. The four readers tested averaged .49 words per second when reading from the first halves, as against .33 words per second when reading from the last halves." [4] He gives three probable factors which coöperate to produce this result, namely, the tendency of English to place the accent upon the first part of the word, the preponderance of the number of suffixes, and the time order in ordinary inter-association of syllables.

Interrelational combinations among the various independent factors of reading Chinese. I made early in 1929 at Stanford University the first experimental approach to this problem of partial exposure in the case of Chinese characters. The same material used in my former experiment on reading-direction and character-position [5] was utilized in this experiment, employing exactly the same procedure with the following adaptation. Every sentence in the various series of direction-position combinations was cut in the middle into two halves so that the entire selection became doubled. The resulting combinations are 32 instead of 16 as was the case in whole-character. This may be clearly made out from a sample in Fig. I in comparison with Fig. 1 of the former report. Every sentence in Series I is the corresponding half of every sentence in Series II. Instead of using arbitrary symbols to represent the direction-position combinations as formerly, the position and sequence of 'AB' are used to represent, in a more direct manner, the various combinations. The bar beside the symbol 'AB' in various positions denotes that *that* half of the sentence of 7 characters is kept intact. Since there are altogether 8 selections for each of the original 16 combinations, each of the resulting 2 series of 32 combinations of opposite

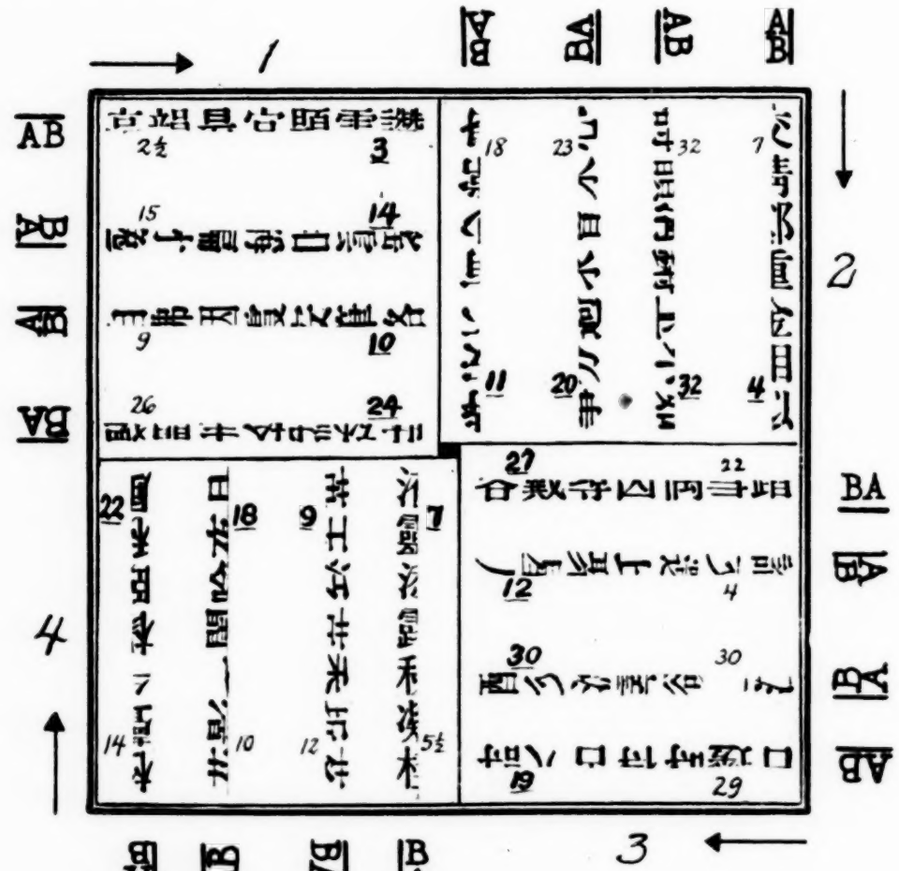
[4] E. B. Huey, *op. cit.*, 96–97.

[5] S. K. Chou, Reading and legibility of Chinese characters: I. Influence of reading-direction and character-position upon speed, this JOURNAL, 1929, 12, 163.



I

FIG. I. Sample of reading material of halt-characters in various direction-position combinations. Series I and II are complementary opposite halves of the corresponding sentences.



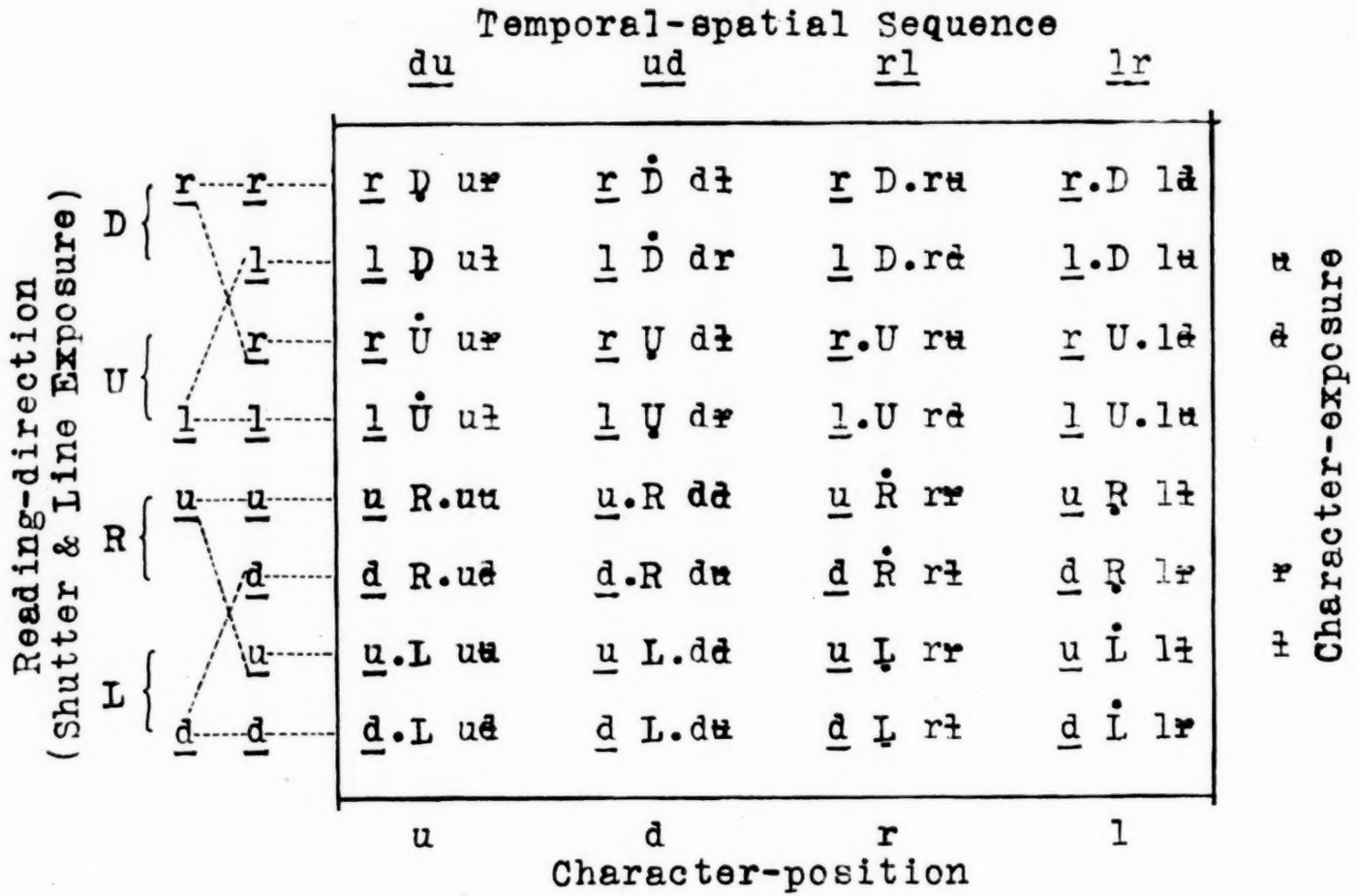
II

FIG. II. Rank orders of speed (heavy, underlined) and reproduction in reading are written beside every half-character sentence.

half-character sentences must have only half that number, *i.e.* 4 selections to every combination; because the same subject was to read the opposite halves of 2 *different* selections.

A system of notation. These various factor-combinations need a complete and consistent system of notation in order that they may be freely represented and conveniently worked upon both during experimentation and during treatment of data (Fig. II). As formerly, capitals (D, U, R, L) denote reading-direction and small letters (u, d, r, l) character-position. The same small letters representing the latter also represent the half-characters, the hyphen breaking them thus signifying the fact that a specific symbol is with reference to that *half* of the 7 characters in the sentence denoted by the symbol. Since this is not possible in typesetting, the right pair of the parenthesis following the different letters, u), d), r), l), also denotes the corresponding halves of the character. Two ways of representing the temporal-spatial sequences are adopted: one is by the underlined (italicized in print) double-letters (*du*, *ud*, *rl*, *lr*) as formerly used, and the other by placing a dot at the side of the reading-direction symbol (*e.g.*, R.). Supposing the reading-direction symbol to be one of the 7 characters in any one sentence, a dot beside any side of it means that, during reading, the eyes move from *that* side of the first character to the *adjacent* side of the next character. This simpler notation is necessary, because the underlined (italicized) double-letters, if written in the total formula representing one combination of all reading factors, would make it unduly long and cumbersome. Furthermore, the temporal-spatial sequence in any factor-combination is only a deduced fact and hence should be represented only secondarily. The underlined (italicized) double-letters are useful when the temporal-spatial sequences alone are to be specifically referred to.

Significance and distinction of shutter- and line-exposure. Since the half-characters in a line may be in any of the 4 possible positions to be read from any of the 4 possible directions, it is clear that they may occupy any of the 4 possible halves of the two vertical and horizontal lines. In



NOTATION: I. Reading-direction II. Character-position III. Character-exposure IV. Shutter-line-exposure

D = downward	u = upright	ʉ=u)=upper half	u = upper half
U = upward	d = upside down	ḋ=d)=lower half	d = lower half
R = rightward	r = turned right	r=r)=right half	r = right half
L = leftward	l = turned left	ɬ=l)=left half	l = left half

Fig. 11. Factor-combinations of the various reading factors.

order to denote the position of the entire line, irrespective of the half-characters, another similar but different set of symbols is needed. This is conveniently supplied by underlining (italicizing in print) the respective *single* small letters already employed as symbols for character-positions. Because the underlined (italicized) *double*-letters are always treated as one whole symbol for temporal-spatial sequence, their partial identity with the former creates no confusion.

A closer look at Fig. I will bring out the fact that the cut side of the half-characters in the line reaches clear to the edge of the printed gummed paper while the other side has some vacant space. This difference is practically justifiable because the original line of whole-characters was not cut clear to the edges of every character. In order to equalize this difference and to compensate the fact of dissimultaneity of exposure of any one pair of the quadrant shutters in the tachistoscope,[6] *that* pair of the shutters corresponding to *that* half of the entire line was opened every 8 exposures, depending upon the order of the reading-direction. Thus, the shutter-exposure, *i.e.* whichever pair of the quadrant shutters is to be opened, is made identical with the line-exposure. Hence, the underlined (italicized) single-letter represents both the line-exposure and the shutter-exposure.

The whole system of notation is schematically shown in Fig. II. The scheme of this chart is important because all results will hereafter be comprehensively presented exactly in this fashion. Columns have the character-positions in common, which are labelled at the bottom, the basal position. Reading-directions together with shutter- and line-exposure run in rows and are labelled at the left side. The patterns of temporal-spatial sequences on the top, the primary position, and of character-exposures on the right should be kept clearly in mind by the aid of the following configurations of dots (Figs. III and IV).

The half-character experiment. Each of the two series of *materials* (opposite half-character sentences) consisting of ½

[6] S. K. Chou, A quadrant tachistoscope for studying the legibility of Chinese characters, this JOURNAL, 1929, 12, 178–186.

Fig. II. Factor-combinations of the various reading factors.

FIG. III. Temporal-spatial sequence patterns.

(Compare Fig. II.)

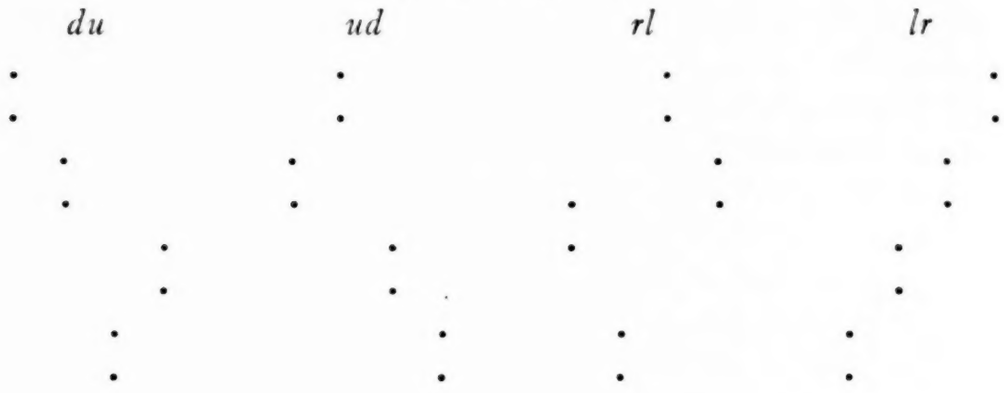
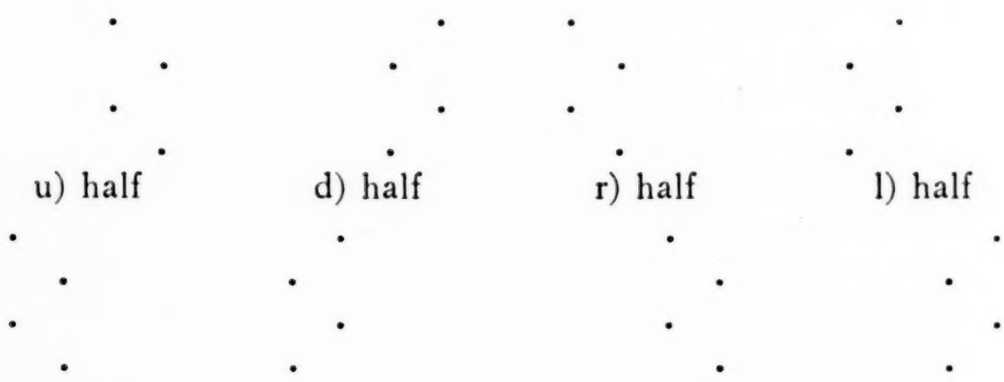


FIG. IV. Character-exposure patterns.

(Compare Fig. II.)



of the total 32 factor-combinations of 4 selections each, the other ½ coming from different selections, was presented to alternate subjects by the technique of *simultaneous voluntary maintenance of exposure* with the Quadrant Tachistoscope or Bradyscope.[7] The order of exposure of the 128 half-character sentences is such that every reading factor is compensated. The reading-direction is changed every 8 exposures, the shutter-exposure and hence the line-exposure changing with it.

Sixteen Chinese *subjects* served in the experiment on Series I and II alternately (shown in the sample in Fig. I, opposites of half-character sentences) as they came to the laboratory. The experiment took on the average about an hour and a

[7] S. K. Chou, Reaction-keys and a new technique for reading-reactions, *Amer. J. Psychol.*, 1929, 41, 469–473. Cf. Tachistoscope versus Bradyscope, *Amer. J. Psychol.*, 1930, 42, 303–306.

half but one or two spent as much as three hours. The novelty of figuring out the entire sentence of 7 half characters is at the same time challenging to some and despairing to others.

The following detailed *instructions* were read to every subject. Verbal explanations were given to some who demanded or needed them.

"The purpose of this experiment is to find out not individual reading ability but the effect of exposing only one half of a Chinese character on average speed and comprehension of reading in different persons. You are requested to follow the instructions very closely and faithfully in reading throughout the entire experiment.

"Now, look attentively at the cross of the window in the hood of the apparatus and at the same time, while holding your pen in your right hand, keep one of your right fingers barely touching the key at your right. At the signal 'Ready! Go!', press the key down hard and hold it there. This will immediately open the window exposing a sentence of seven Chinese half-characters, in each case the other half is cut off. Read silently to yourself these half-characters as quickly as you can. Relying upon these half-characters shown, try to figure out the whole of every character. When you have decided upon the identity of the complete characters, quickly release your finger from the key. But never release it while you are reading, because this will immediately close the window. Remember to hold the key down tightly as long as you are reading. I will start the stop-watch at the instant the window opens and stop it when the window closes. This will record the time you take in reading the whole sentence.

"After reading, write down immediately on the record-sheet before you from left to right the entire sentence of seven whole characters as you think they are in the order you read them. Write each sentence opposite each number and proceed downward beginning with the left column. If you are not sure of any whole character, put a cross in place of it. Write down only the whole character, because only the whole character correctly reproduced will be counted.

"The seven half-characters are all either the upper half, lower half, right half, or left half of the whole characters. The position of all the characters in successive exposures are either upright, upside-down, tilted to the right, or tilted to the left depending upon chance order. You will read eight cards in succession in either one of the four directions, namely, downward, upward, rightward, or leftward. The order of the directions in successive series of eight cards is marked by the half arrow-head on the record-sheet. Do not care about the position of characters. Read always in the direction you are told to read. There will be 128 cards to read and to be written down on four pages. In case of vertical (downward and upward) readings, right and left pairs of the window shutters will be opened for eight times in succession showing respectively right and left halves of the entire line. In case of horizontal (rightward and leftward) readings, upper and lower pairs of the window shutters will be opened for eight times in succession showing respectively upper and lower halves of the entire line. Do not pay any attention to which pair of the shutters will open. The only thing to do is to read in the proper direction every time, regardless of character-position or shutter-exposure.

"I will tell you in which direction you are going to read in every card within any one series by saying, for example, 'Upward! Ready! Go!' It is important that you

should keep the same attitude and method as constant as possible in reading and recording throughout the entire experiment."

I have tried to explain in detail the nature and purpose of the experiment in the instruction. In working with new subjects, I deem it better to tell what an experiment is about than to keep them *wondering* over the tricks of it. The reading-time in this experiment was recorded in .1 second. Ample time for rest was automatically allowed, since for every 8 exposures I had to reset the switch controlling the shutters of the tachistoscope and after 64 exposures to change the card-holder. The general procedure of conducting the experiment was in the main the same as in the *direction-position experiment.*

In view of the fact that individual differences in both reproduction and speed are great, yielding sometimes very unusual distributions for both and frequently producing a very wide range in speed, I have calculated the successive

TABLE I

SUMMARY OF HALF-CHARACTER EXPERIMENT

Reading-directions	4		
Character-positions	4		
Opposite halves	2	*Successive Products*	
Selections	4		
Characters	7	Half-characters	128
Subjects	16	Total characters	896
Characters read by all subjects			14336

* * * * *

Reading-directions	4		
Character-positions	4		
Opposite halves	2		
Selections	4	Factor-combinations	32
Subjects	16	Records for each combination	64
Reading-time records from all subjects			2048

* * * * *

N for each factor-combination	64
N for each factor-combination *of* reading-direction, character-position, character-exposure, shutter-&-line-exposure *or* temporal-spatial sequence	512

means by the long method from the successive totals of all records *ungrouped* for every factor-combination in both cases. The following table of figures should fix well in mind the total number of characters and the total records of reading-times of all 16 subjects. The number of cases of the successive means is also shown (Table I).

Reproduction of whole-character from half-character. There are 20 independent factor-combinations arising from all 5 factors. These are separately ranked outside of the square (Tables II and III). The shutter-and-line exposure combinations come from alternate rows as shown by the dotted lines connecting them. The figures are the means for the number of whole-characters correctly reproduced (Table II) out of a possible 7 in the sentence and for the reading-time in hundredths of a second (Table III). The underlined figures are rank orders. It should be pointed out that, while the significance of the absolute difference between any two factors or factor-combinations depends upon the reliability of the difference, *only the relative difference in rank order among the different factors or factor-combinations is primarily concerned in the following discussions.*

Keeping character-exposure constant while varying all the other 4 factors, *right*, r), and *left*, l), half-characters yield on the average more reproduction than upper and lower halves. *Left* and *upper*, u), halves are much more suggestive of the whole-character than *right* and *lower*, d), halves. In fact, reproducing 4.62 whole-characters from the left half under all sorts of variable conditions is only 2d to reproducing 4.87 of them all upright (u) from any half; while reproducing 3.38 from the lower half is 20th, the least conducive to reproduction not only when keeping the character-exposure constant but irrespective of whatever factor is kept constant. This is also shown by the fact that to figure out the whole-character from the lower halves takes the longest time, 11.93 sec. (Table III).

The explanation for this result probably rests on the fact that most of the characters have their radicals on either the top or left side of the character. That the upper should be

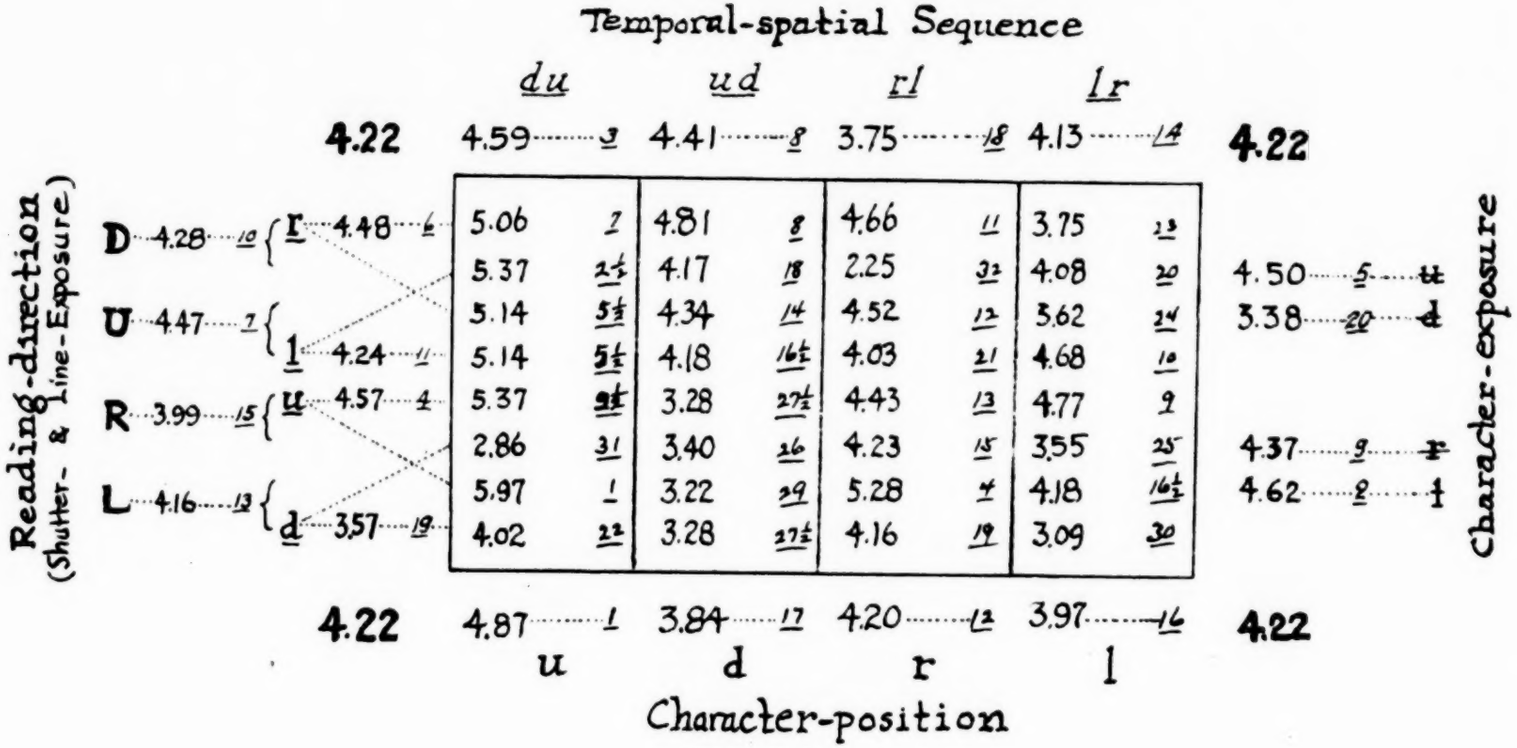


TABLE II

REPRODUCTION OF WHOLE-CHARACTERS [8]

[8] As in the diagram shown in Fig. II, read horizontally in rows for reading-direction and shutter-and-line exposure. For character-position, read vertically in columns. For temporal-spatial sequence items, compare Fig. III. For character-exposure items, compare Fig. IV. Underlined smaller figures are rank orders, of which there are 32 within the square and 20 outside of it. *Cf.* Fig. V and Tables IV, V, and VI below.

TABLE III

SPEED IN HUNDREDTH SEC IN READING HALF-CHARACTERS

dominant over the lower is perhaps the natural phenomenon of perception. But it is of some importance to note that, being written in the order of from left to right within the character, the left side of the character may thus acquire an ascendency over the right side.

The normal bottom-to-top (*du*) sequence yields 4.59 whole-characters; and upper (*u*) half of the line-and-shutter, irrespective of the half-characters, the next number, 4.57, although their relative speed is quite the reverse (Table II). Right (*r*) and upper (*u*) halves of the shutter-and-line give faster reading and yield more reproduction than the left (*l*) and lower (*d*) halves (Table III). This faster reading speed in favor of the right half of the line and shutter may be influenced by the fact that the reaction-key is on the right side of the tachistoscope. Furthermore, all except 3 of the 16 subjects were tested and found to be right-eyed (and hence indirectly right-handed in the majority) by the use of the Miles' A–B–C Vision Test.[9] The speed of reading half-characters for reproduction of whole-characters, while the subject *maintains* exposure by the right half of the shutter with the right finger, is probably conditioned favorably by right-eyedness and by right-handedness. It should be pointed out that this is immaterial to character-exposure because every half of the character is represented in every half of the line or shutter.

Downward (D) reading of the half-characters for reproduction is not much faster in speed and yields even appreciably less reproduction than upward (U) reading. This shows that reading-direction is comparatively immaterial under these circumstances. On the whole, keeping reading-direction constant while varying the other 4 factors, there is not much difference in relative speed and reproduction; but leftward (L) reading is both faster and gives more reproduction than rightward (R) reading. The difference may not be *sufficiently* significant by itself but it confirms the result obtained from the last experiment using whole-characters and hence must be *somewhat* significant.

[9] W. R. Miles, Ocular dominance demonstrated by unconscious sighting test, *J. Exper. Psychol.*, 1929, 12, 113–126.

The frequency distribution of the number of whole-characters correctly reproduced for each of the 32 factor-combinations within the square of Fig. I is plotted on Fig. V. The arrangement of the distributions is exactly the same as that within the square. The figure within the curves are the *total* number of whole-characters correctly reproduced.

The best reproduction of 5.97 whole-characters is leftward reading of upper half-line of upright upper half-characters, *u*Luu), (Table II). The distribution is skewed to the right, *i.e.* there are more perfect reproductions (7 whole-characters) than in any other combination and none in which only 0, 1, or 2 whole-characters are reproduced in the sentence. The sequence is left-to-right (*lr*). The poorest reproduction of 2.25 whole-characters is downward reading of left half-line of lower half-characters tilted to the right, *l*Drd). The distribution, on the other hand, is skewed to the left, *i.e.* there are more cases where no or only a few whole-characters are reproduced than in any other. The sequence is right-to-left (*rl*). These two factor-combinations are also the fastest and the slowest respectively among the 32 combinations.

Combinations containing upright half-characters all have extremely asymmetrical distributions, except in the case of leftward reading of lower half-line of upright lower half-characters, *d*Lud), which is very unusually normal.

Individual differences in reproduction are very great. Subject 8W reproduced correctly 687 whole-characters out of a possible total of 896 with a mean of 5.37 to the sentence. This subject happens to be the only one who had taken the former experiment on whole-character sentences, which are cut into halves for the present experiment. He was the second fastest reader in the former and *the* fastest in the present experiment. Subject 7H reproduced only 380 whole-characters correctly with a mean of 2.97 per sentence, although he is not the slowest to figure out the 'whole' from the 'half.' About half of the subjects yield distributions approaching normality.

The final rank orders of both reproduction and speed in the various factor-combinations can be directly compared by

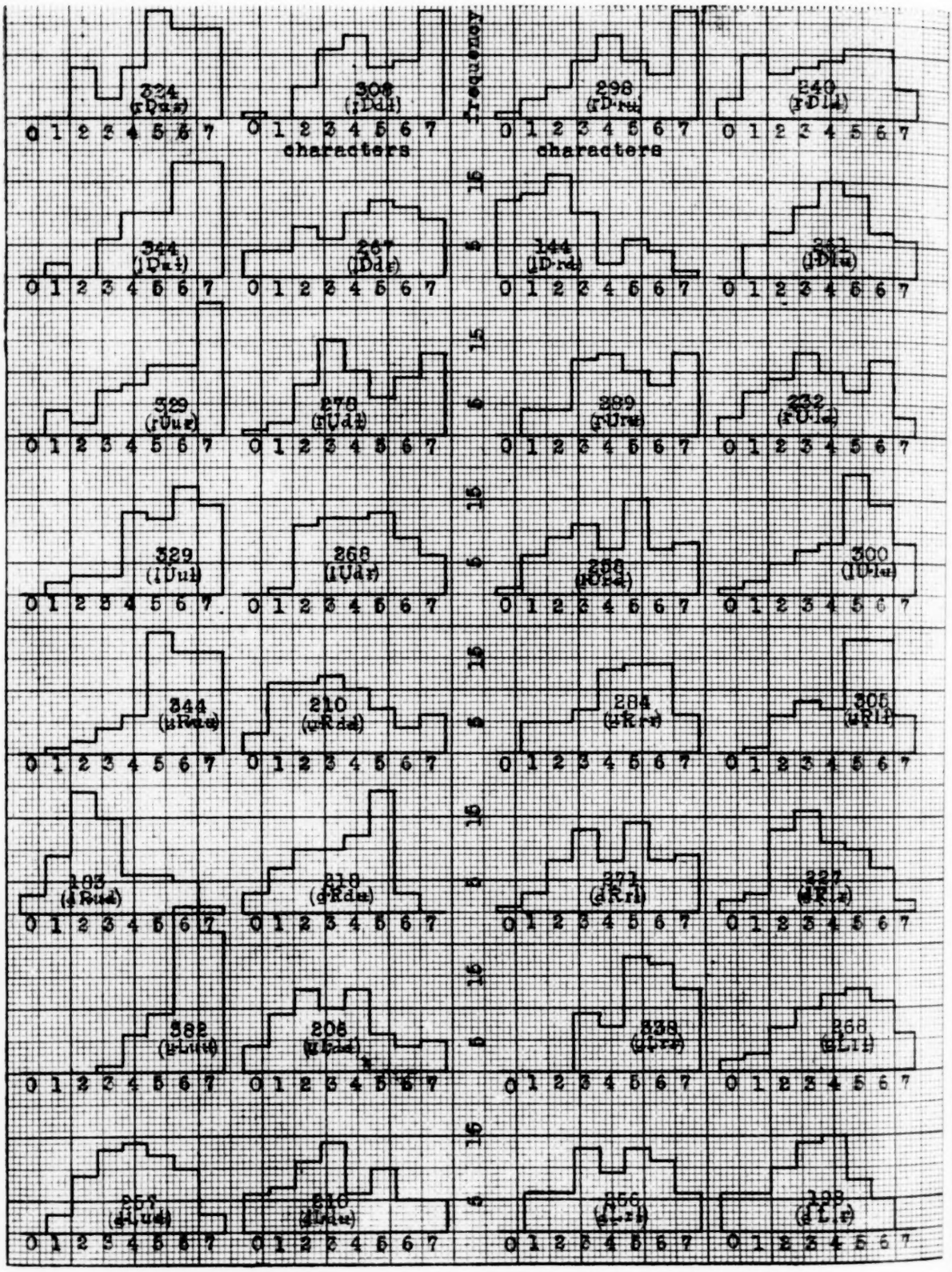


FIG. V. Number of characters correctly reproduced. (Compare Fig. II.)

referring to the figures beside the half-character sentences in Fig. I. Reproduction and speed among the various combinations are highly correlated. The rank-order correlation coefficient (rho) between them is found to .83 when both are based upon the mean of all subjects, but .94 when the average rank of the separate ranks of mean speed of all subjects is taken in place of that of the mean speed of all subjects.

Relative hindrance of the various reading factors. Since the two experiments on *whole-* and *half*-characters were performed on identical material under otherwise similar circumstances by the same technique of *simultaneous voluntary maintenance of exposure* with the Quadrant Tachistoscope or Bradyscope, the results are strictly comparable so far as reading speed is concerned. They have all been reduced to 1 sec in the comparison (Tables IV, V, and VI).

TABLE IV

READING WHOLE-CHARACTERS (SPEED: 11 SUBJECTS, 4 SITTINGS EACH)
(See Note to Tables II and III)

			du		*ud*		*rl*		*lr*	
	2.17		2.09	2½	2.27	*12*	2.15	*4*	2.16	*5*
D	2.17	6½	1.99	*2*	2.29	14½	2.21	*10*	2.17	*6*
U	2.22	*9*	2.24	*11*	2.18	7½	2.19	*9*	2.28	*13*
R	2.19	*8*	2.00	*3*	2.33	*16*	2.25	*12*	2.18	7½
L	2.09	2½	1.95	*1*	2.12	*5*	2.01	*4*	2.29	14½
	2.17		2.05	*1*	2.23	10½	2.17	6½	2.23	10½
			u		*d*		*r*		*l*	

TABLE V

READING HALF-CHARACTERS (SPEED: 16 SUBJECTS)
(See Note to Tables II and III)

			du		*ud*		*rl*		*lr*	
	10.84		10.58	*3*	10.45	*2*	11.17	*10*	11.22	*11*
D	10.60	*4*	8.88	*1*	9.95	*3*	11.53	*11*	12.02	*16*
U	10.82	*5*	9.03	*2*	11.56	*12*	11.12	*9*	11.57	*13*
R	11.02	*7*	10.40	*5*	11.58	*14*	11.05	*8*	11.02	*7*
L	10.95	*6*	10.06	*4*	11.14	*10*	10.85	*6*	11.80	*15*
	10.84		9.58	*1*	11.05	*8*	11.15	*9*	11.60	*12*
			u		*d*		*r*		*l*	

TABLE VI

READING HALF-CHARACTERS (REPRODUCTION: 16 SUBJECTS)
(See Note to Tables II and III)

			du		*ud*		*rl*		*lr*	
	4.22		4.59	*2*	4.41	*4*	3.75	*12*	4.13	*8*
D	4.28	*5*	5.22	*1*	4.49	*4*	3.45	*14*	3.91	*12*
U	4.47	*3*	5.14	*2*	4.27	*7½*	4.27	*7½*	4.08	*11*
R	3.99	*9*	4.13	*10*	3.35	*15*	4.33	*6*	4.16	*9*
L	4.16	*7*	4.99	*3*	3.25	*16*	4.72	*5*	3.64	*13*
	4.22		4.87	*1*	3.84	*11*	4.20	*6*	3.97	*10*

It takes on the average 2.17 sec to read out aloud a sentence of 7 whole-characters in all positions from all directions by all subjects, but the time taken to read it in half-characters in order to reproduce as many as possible in 'whole' is 10.84 sec, just about 5 times as long. Subject 8W, who is the second fastest reader in the whole-character experiment, and *the* fastest in the half-character experiment, takes on the average not quite double his time for 'wholes.' This was probably accounted for by the fact that the material was already more or less familiar to him. All subjects reproduce on the average 4.22 whole-characters out of a sentence of 7 half-characters, yielding an accuracy of just about 60 percent.

The comparative effect of reading-direction, temporal-spatial sequence, and character-position in the case of whole-characters on speed, and of character-exposure and shutter-and-line-exposure, in addition, in the case of half-characters both on speed and on reproduction, is summarized in Tables VII, VIII, and IX.

RELATIVE EFFECTS OF VARIOUS READING FACTORS

TABLE VII

WHOLE-CHARACTERS: SPEED

Fastest		Slowest		% Increase
L	2.09	D, U, L	2.19	4.98
du	2.09	*ud, rl, lr*	2.19	4.98
u	2.05	d, r, l	2.21	7.92

TABLE VIII

HALF-CHARACTERS: SPEED

Fastest		Slowest		% Increase
D	10.60	U, R, L	10.90	9.56
ud	10.45	*du, rl, lr*	10.96	14.97
l)	10.38	u), d), r)	10.98	17.86
r	10.25	*u, d, l*	11.02	24.00
u	9.58	d, r, l	11.25	54.81

TABLE IX

HALF-CHARACTERS: REPRODUCTION

Best		Worst		% Decrease
U	4.47	D, R. L	3.10	30.64
u	4.57	*d, r, l*	3.08	32.60
du	4.59	*ud, rl, lr*	3.07	33.10
l)	4.62	u), d), r)	3.04	34.20
u	4.87	d, r, l	3.00	38.40

The reliability of the different measures is not so critical, since it is the *relative standing* between them that is wanted. The differences in speed between the three factors in whole-characters (Table VII) are obscured by reducing the .02 sec to 1 sec.

When keeping the direction of reading constant while varying the other factors, leftward reading (L) of whole-characters (Table VII) and downward reading (D) of half-characters are the slowest among the fastest records of any of the other constant factors while varying the rest. Upward reading (U) yields the best reproduction among other reading-directions, but is the worst among the best of any of the other constant factors while varying the rest (Table IX). This confirms my contention set out in my former reports that reading-direction is comparatively far less important as a factor than either temporal-spatial sequence or character-position in the case of whole-characters. It is also less important than either character-exposure or shutter-and-line-exposure in the case of half-characters as is shown in this report. *Hence it should not receive so much attention.*

Temporal-spatial sequence is the next least important factor in both whole- and half-characters so far as speed is concerned (Tables VII, VIII), but is more important than

shutter-and-line-exposure in the reproduction of whole- from half-characters (Table IX). Left half-character, 1), under variable conditions, is most suggestive of the whole-character, as is revealed by the fact that it is the fastest and gives the best reproduction among any other halves (Tables VIII and IX).

The different shutter-and-line-exposure positions do not have the same importance for speed and for reproduction. While right half of the shutter-and-line (*r*) is quicker to read (Table VIII), upper half (*u*) yields more reproduction (Table IX). In fact, shutter-and-line-exposure is a more important conditioning factor for speed than for reproduction, since the fastest reading of right-half (*r*) of the line-and-exposure is next only to the fastest reading of upright characters (u) (Table VIII).

Character-position is by far the most important conditioning factor both for speed and for reproduction; since the normal upright position yields the best reproduction in the shortest time, in spite of the fact that all factors of reading-direction, character-exposure, shutter-and-line-exposure, and temporal-spatial sequence are heterogeneous. This is made more significant by the fact that the average speed in reading half-characters in other positions is increased 55 percent (Table VIII), with even 38 percent fewer reproduction of whole-characters (Table IX); although the effect is much less (8 percent, Table VII) in simply reading aloud the whole-characters. This is of little wonder because characters are usually printed upright and never in any other position. What does research amount to but common sense!

Summary. When a sentence of 7 Chinese characters is cut in the middle along the line, the original 16 combinations of reading factors resulting from 4 reading-directions and 4 character-positions become double, yielding 32 opposite half-character sentences. This gives rise to three more independent reading factors, namely, character-exposure, line-exposure, and shutter-exposure. Character-exposure denotes whichever half of the *characters* in the sentence is exposed, irrespective of other things. Line-exposure denotes whichever

half of the *line* is occupied by the half-characters, irrespective of the character-exposure. Shutter-exposure denotes whichever half of the shutter-window is opened to expose the half-character sentence. Shutter-exposure is made identical with line-exposure so that the window will open always *away* from the cut center *toward* the border of all characters.

From the results of 16 subjects, left and upper halves of Chinese characters have been found more suggestive of the whole-characters than either right or lower halves, since they take shorter time to read and yield more reproduction of the supposed whole-characters. This may be accounted for by the fact that most of the characters have their radicals either on the top or on the left side of the character and also that the left and upper sides of the character are mostly written before the other two sides.

The fact that right and upper halves of the shutter and line give faster reading and yield more reproduction is perhaps due to primacy and right-handedness. The subjects used the right hand to press the key for opening the shutter-window. They were tested for eyedness and hence indirectly handedness in the majority. Thirteen out of the sixteen subjects are presumably right-handed.

Of the different reading factors, reading-direction has the least hindrance upon speed and character-position the most. Temporal-spatial sequence has more hindrance on reproducing the whole-character from the 'half' than upon the speed of read- the half-characters. Half-character has more hindrance on both speed and reproduction than temporal-spatial sequence.

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SOME SIMPLE APPARATUS FOR SERIAL REACTIONS

BY J. F. DASHIELL

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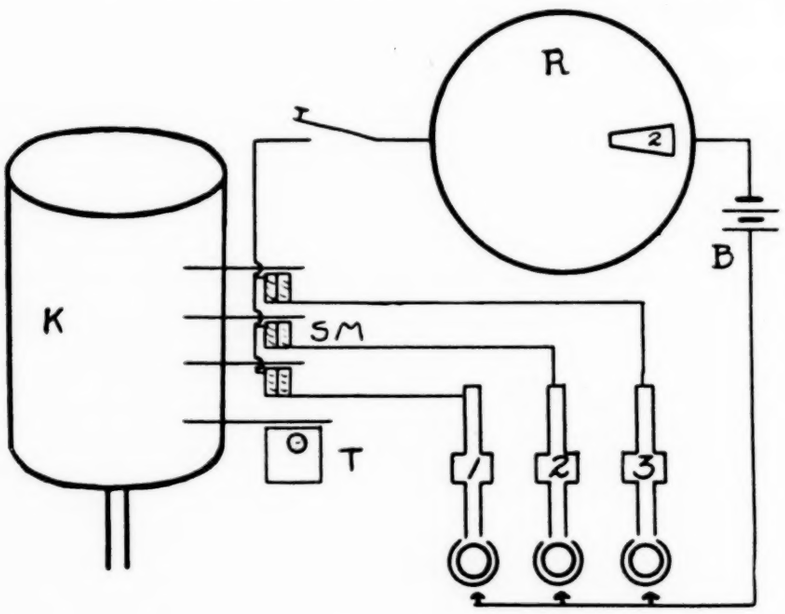
R. H. Seashore [1] has made a useful summary of twenty-three techniques that have been used to measure serial action of discrimination or of pursuit type. The present writer, having had gratifying results with three of his own devising, that were fairly simply constructed, offers them in addition.

(1) The Ranschburg exposure apparatus can be adapted to the measurement of serial choice reactions by being wired simultaneously in circuits with a number of different 'tele-



graph' keys and corresponding signal markers. An arrangement used by the writer in a study of psycho-motor efficiency [2] is illustrated in Fig. 1. Each of the three telegraph

[1] Seashore, Techniques for measuring serial action, *J. Exper. Psychol.*, 1928, *11*, 45-55.

[2] Variations in psycho-motor efficiency in a diabetic with changes in blood-sugar level. *J. Comp. Psychol.*, 1930, **10**, 189-197.

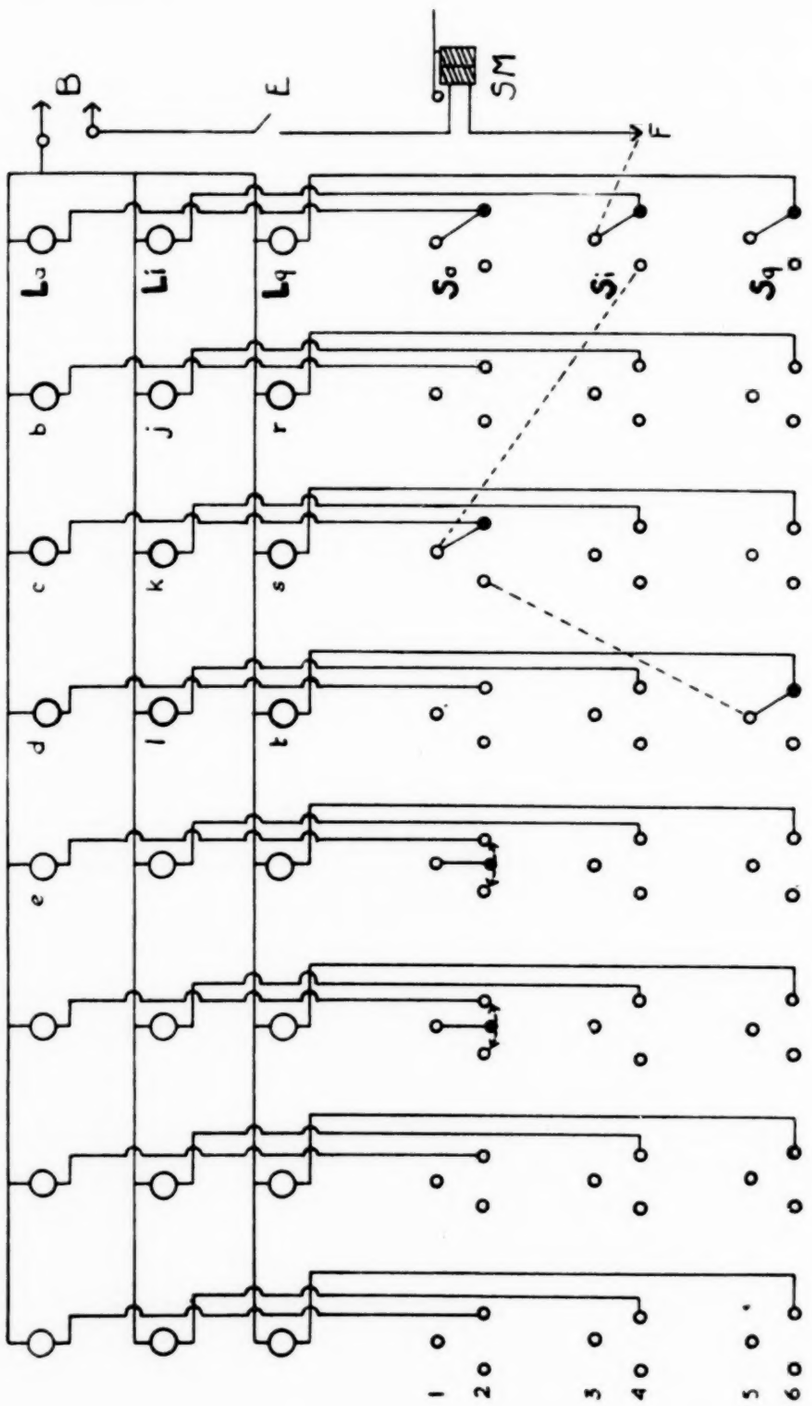
keys (*1*, *2*, *3*) is wired in circuit with a signal marker or recording pen, *SM*, and a Ranschburg exposure apparatus, *R*. When a key is pressed, the closed circuit actuates an electromagnet within the case of the exposure apparatus, which draws a revolving carriage around one notch and so brings under the aperture the next item of a series inscribed on a cardboard disk riding on the carriage. The speed of presentation of the successive stimuli is thus governed automatically by the speed of the reactions made. The kymograph or polygraph record will show which reactions have been made from time to time, so that errors can be detected by comparison with the stimulus series; and by use of a time marker, *T*, the speed for the whole series or for any part can be determined.

The Ranschburg apparatus is one depending for consistently smooth operation upon a delicate adjustment of a number of screws; and the experimenter must be at pains to attend to them regularly.

(2) Manipulation of electric lights has a certain amount of intrinsic interest for naïve subjects. An arrangement set up by the writer and used in the North Carolina laboratory in a variety of problems,[3] consists of a bank of 24 miniature lamps arranged in three rows of eight to the row on a vertical panel, and with their corresponding individual switches (two-point type) similarly arranged on the lower half of the panel. In use, a single light is flashed on as the first stimulus, which S extinguishes by locating and throwing the corresponding switch; whereupon a second lamp lights up; and so on until the 24th lamp is extinguished, when a red 'stop' light appears at the top of the panel. The wiring system as it appears on the reverse face of the panel is shown in Fig. 2. At the beginning of an experiment all switches are in the closed position (in contact with the right-hand post). From one pole of the battery *B* wires are run to all lamps, *L*, *L*, as if in parallel, and through them to the 'closed' (right-hand) contact of the switches, *S*, *S*, corresponding respectively to them. From the other pole of the battery a wire is plugged

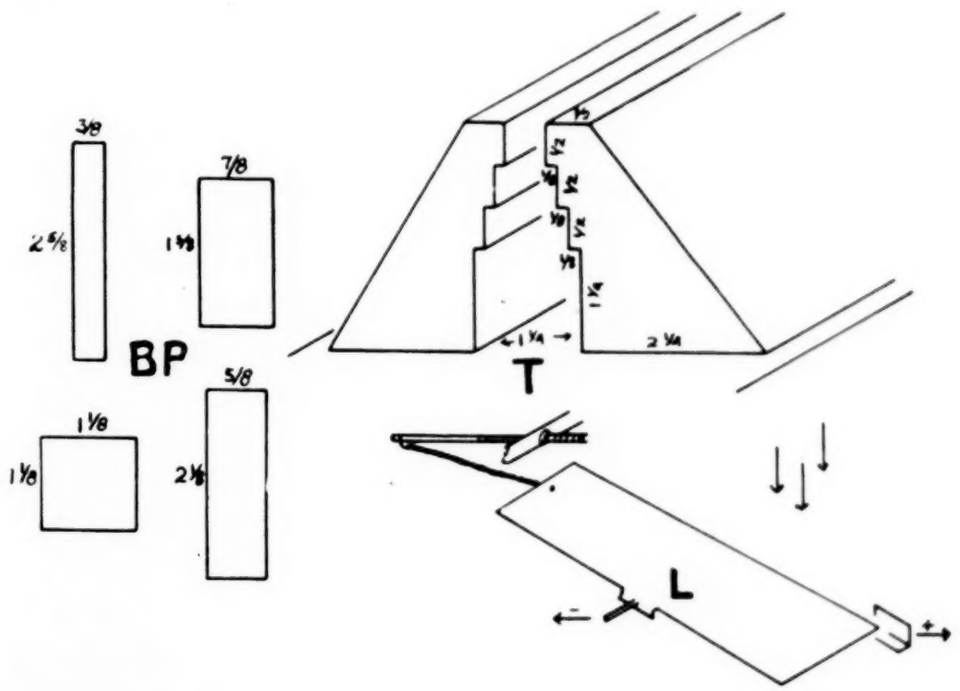
[3] W. W. Rogers employed apparatus described under (2), (3), and (4), as part of his set-up for a doctoral dissertation on "Factors involved in the formation of a multiple habit from disparate activities," much of which is to appear in article form soon.

in at the head of a switch (as *Si*), in such manner that when E closes his control switch *E* at the start the corresponding lamp (as Li) flashes up for S. From the 'open' (left-hand) contact of each switch a flexible wire leads to the head of some other switch, so that when S throws open the former he



automatically completes wiring to the latter (as Sc); and this, being in its original 'closed' position, lights up its corresponding lamp (Lc). With the use of flexible wires and plugs, E can set any desired sequence of lights for a given test series. The last light and switch in a given series are similarly wired to the red stop signal (not shown in figure). Recording of S's progress is done accurately with a signal marker or recording pen, *SM*, which records each momentary break when light is shifted from one lamp to the next, writing on a kymograph or polygraph along with a time marker.

(3) An apparatus useful for measuring serial reactions where for any reason vision is not to be involved can be made



in simple form of wood. As built by the writer, it consists essentially of the non-visual presentation of a series of differently shaped blocks each of which S is to discriminate and to fit to its own proper hole in a brass plate through which it can be dropped. Four forms of disk-shaped blocks are used, with a brass plate bearing four holes (Fig. 3, *BP*), each of which is designed to admit one of the blocks only.

For control of presentation of the blocks a tilted trough (Fig. 3, *T*) is used down which they gently roll in an order

determined by E, to a stop just outside the lower end and at S's hand. The dimensions of the trough are cut (in three pieces) to accomodate the various shapes of blocks without their binding nor running abreast. Dimensions are shown in Fig. 3 (in inches because done at a cabinet shop). The blocks are cut in the following lengths and diameters: ¼″ x 2½″, ½″ x 2″, ¾″ x 1½″, 1″ x 1″. When dropped through the brass plate a block falls upon a padded aluminum lever 8″ x 16″, (Fig. 3, *L*), delicately balanced by using at one end a light coil spring as a flat spring; and the momentary pressure upon the lever makes an electric contact, serving in turn to close a circuit operating a signal marker or pen. A metal disk, following the last wooden disk of a presentation series, makes contact between two copper strips laid at the lower end of the trough; and the electric circuit thus closed rings a 'stop' bell. S may work with arm through a slitted screen.

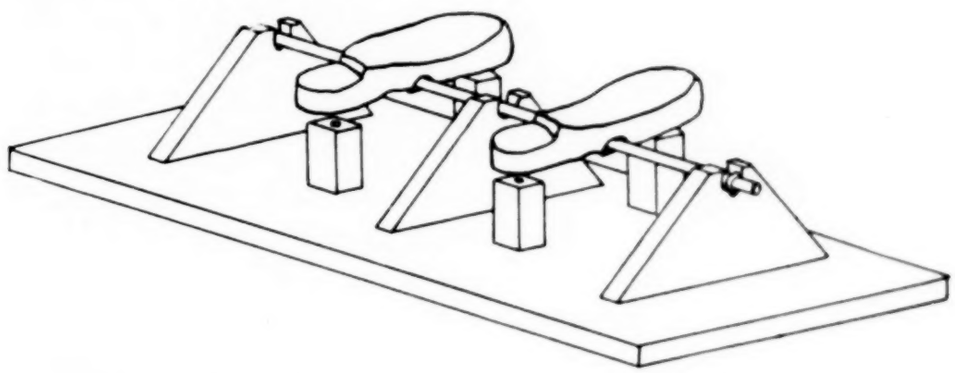
This set-up is cheap enough to construct, but calls for accurate adjustment of dimensions.

The three forms of apparatus vary much in their particular features, making one or another adaptable to differing experimental problems. The Ranschburg set-up does not force S to correct errors but on the other hand permits separate measurements of speed and of accuracy; it allows presentation of a very wide variety of visual stimuli; a series of 60 stimuli is the maximum; and it may be used to some extent to study rate of learning, both of reactions to individual items and of the order of sequence. The bank of lamps forces S to correct an error before proceeding, yielding a single total score; the stimulus series is limited to 24 (in the writer's size of panel); and some measurement of learning, though not great, is made possible. The blocks-and-plate apparatus requires S to correct errors; stimulus series may be unlimited in length, and some variety of order is possible; cutaneous and kinesthetic stimulus-presentation is used in contrast with that in practically all other serial choice techniques; and the learning of many part-activities is involved.

All three forms of apparatus may be used for studying constancy of attention or condition, for studying simultaneous disparate activities or attention-span, for studying learning

of one or of multiple performance, etc. All possess the advantage of quick changeability of stimulus-series; and the advantage of graphic recording of time for each component reaction as well as for the whole series.

(4) Description of an apparatus for measuring serial reactions not involving discrimination may be added to the preceding, as the writer and others have found it useful in connection with them. It consists essentially of two pedals which S is instructed to keeping turning in forward-backward manner simultaneously but in opposite and alternating directions. (*Cf.* Fig. 4.) The pedals are of wood, shaped



somewhat like a bootblack's shoe-rest, grooved and balanced across a round steel bar set in wooden frame-work forming the pedestal. On under side of heel and toe they bear points that lower into mercury cups set on the pedestal. The two forward cups are wired together to one pole of an electric circuit, the two rear cups to the other pole; and the heel point of either pedal is wired in connection with the toe point of the other; so that a circuit is closed when the heel of one pedal and the toe of the other are depressed simultaneously. For more detailed analysis two separate circuits are used, left-toe-right-heel and right-toe-left-heel.

This apparatus is useful for the study not of reactions to externally presented series of stimuli, but of the organization of a simple pattern of circular reaction with kinesthetic and auditory controls. It is of particular advantage when used along with other tasks for S, where the maintenance of disparate activities is under investigation.

(Manuscript received August 20, 1929)

A MODIFICATION OF THOMSON'S FORMULA FOR THE CORRELATION BETWEEN INITIAL STATUS AND GAIN, AND ITS STANDARD ERROR

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The problem of the relation of ability to improvability is one of the most interesting and difficult in the field of statistical psychology. There appears to be no unique mathematical solution. One of the most promising approaches has been through the correlation of initial status in a learning experiment with gross gain. This method presupposes that the measurements are in units of work, *i.e.*, that they are records of the amount of work successfully accomplished in a given time. The raw correlation coefficient cannot be used, as the errors of measurement affect it systematically. This fact was pointed out by Thorndike (1) and a special form of the correction for attenuation was derived by Thomson (2), (3) for estimating the true correlation in such cases. He took the score on the first trial (or the sum of the scores on the first few) as the initial status, the score on the last trial (or on the last several) as the final status, and the difference between these scores as the gain. In correcting for attenuation, he took as the reliability of the initial scores their correlation with the scores on the second trial (or group of trials), and as the reliability of the final scores, their correlation with the scores on the next-to-last trial (or group of trials). If the learning curve is curving sharply, and particularly if the initial status and final status are defined in terms of the scores on several successive trials, this method of determining the reliability would result in underestimation. A better method would seem to the writer to be to define the initial status in terms of

[1] The writer is indebted to his colleague, Mr. Jack W. Dunlap, for invaluable assistance in the derivation of the error function.

the sum of the scores on some even number of successive trials, and then determine the reliability by correlating the first and last of these against the middle ones and applying the Spearman-Brown formula or some equivalent, and to do the same for the final status.

The present paper presents a derivation of the correction for attenuation under the conditions above noted, and of an approximation to its standard error.

Let x be an initial true score,
y a final true score,
z a true gain, so that $z = y - x$

(x and y being measured from their respective means). Then

$$\rho_{xz} = \frac{\Sigma xz}{\sqrt{\Sigma x^2 \Sigma z^2}} = \frac{\Sigma xy - \Sigma x^2}{\sqrt{\Sigma x^2(\Sigma y^2 + \Sigma x^2 - 2\Sigma xy)}}. \qquad (1)$$

Let x be measured by fallible scores x_1 and x_3 with errors δ_1 and δ_3, and let y be measured by fallible scores y_2 and y_4 with errors e_2 and e_4. Then

$$x_1 = x + \delta_1, \quad x_3 = x + \delta_3, \quad y_2 = y + e_2, \quad y_4 = y + e_4.$$

We may assume that the errors are uncorrelated with one another and with the true scores, whence

$$\begin{aligned}
\Sigma x_1 x_3 &= \Sigma(x + \delta_1)(x + \delta_3) = \Sigma x^2, \\
\Sigma y_2 y_4 &= \Sigma(y + e_2)(y + e_4) = \Sigma y^2, \\
\Sigma x_1 y_2 &= \Sigma(x + \delta_1)(y + e_2) = \Sigma xy, \\
\Sigma x_1 y_4 &= \Sigma(x + \delta_1)(y + e_4) = \Sigma xy, \\
\Sigma x_3 y_2 &= \Sigma(x + \delta_3)(y + e_2) = \Sigma xy, \\
\Sigma x_3 y_4 &= \Sigma(x + \delta_3)(y + e_4) = \Sigma xy.
\end{aligned}$$

Then from the fallible measures the best estimate (in the probability sense) of Σx^2 is $\Sigma x_1 x_3$; of Σy^2, $\Sigma y_2 y_4$; and of Σxy,

$$(\Sigma x_1 y_2 + \Sigma x_1 y_4 + \Sigma x_3 y_2 + \Sigma x_3 y_4)/4.$$

But

$$\Sigma(x_1 + x_3)(y_2 + y_4)/4 = (\Sigma x_1 y_2 + \Sigma x_1 y_4 + \Sigma x_3 y_2 + \Sigma x_3 y_4)/4,$$

and the former expression is therefore an equally valid estimate of Σxy. Substituting in (1), and calling our estimate of

ρ_{xz}, r_{xz}, we have

$$r_{xz} = \frac{\Sigma(x_1 + x_3)(y_2 + y_4)/4 - \Sigma x_1 x_3}{\sqrt{\Sigma x_1 x_3(\Sigma x_1 x_3 + \Sigma y_2 y_4 - \Sigma(x_1 + x_3)(y_2 + y_4)/2)}}.$$

Call

$\Sigma x_1 x_3/N = a_{13}$, $\Sigma y_2 y_4/N = a_{24}$, and $\Sigma(x_1 + x_3)(y_2 + y_4)/N = a$ (N being the total frequency of the sample measured). Then

$$r_{xz} = \frac{a/4 - a_{13}}{\sqrt{a_{13}(a_{13} + a_{24} - a/2)}}. \tag{2}$$

This is the required modification of Thomson's formula. It should be noted that the a's as defined are product-moment coefficients—the numerators of the corresponding correlation coefficients. The standard error of Formula (2) is then required. The following derivation is an approximation in the sense that it assumes that higher powers in the errors of sampling are negligible in comparison to first powers, and neglects such errors. Certain other assumptions are introduced and explained in the derivation.

Taking logarithmic differentials of (2),

$$\frac{dr_{xz}}{r_{xz}} = \frac{da/4 - da_{13}}{a/4 - a_{13}} - \frac{da_{13}}{2a_{13}} - \frac{da_{13} + da_{24} - da/2}{2a_{13} + 2a_{24} - a}.$$

Squaring, and calling the denominators k's as indicated,

$$\left(\frac{dr_{xz}}{r_{xz}}\right)^2 = \underset{k_1^2}{\left(\frac{da/4 - da_{13}}{a/4 - a_{13}}\right)^2} + \underset{k_2^2}{\left(\frac{da_{13}}{2a_{13}}\right)^2} + \underset{k_3^2}{\left(\frac{da_{13} + da_{24} - da/2}{2a_{13} + 2a_{24} - a}\right)^2}$$

$$- 2\underset{k_1 k_2}{\left(\frac{da/4 - da_{13}}{a/4 - a_{13}}\right)\left(\frac{da_{13}}{2a_{13}}\right)}$$

$$- 2\underset{k_1 k_3}{\left(\frac{da/4 - da_{13}}{a/4 - a_{13}}\right)\left(\frac{da_{13} + da_{24} - da/2}{2a_{13} + 2a_{24} - a}\right)}$$

$$+ 2\underset{k_2 k_3}{\left(\frac{da_{13}}{2a_{13}}\right)\left(\frac{da_{13} + da_{24} - da/2}{2a_{13} + 2a_{24} - a}\right)}.$$

Expanding, summing, dividing by the population and expressing in terms of moment coefficients,

$$\frac{\sigma_{r_{xx}}^2}{r_{xx}^2} = \frac{a^{\mu_2}/16 + a_{13}^{\mu_2} - a_{13}a^{\mu_{11}}/2}{k_1^2} + \frac{a_{13}^{\mu_2}}{k_2^2} + \frac{a_{13}^{\mu_2} + a_{24}^{\mu_2} + a^{\mu_2}4/ + 2a_{13}a_{24}^{\mu_{11}} - a_{13}a^{\mu_{11}} - a_{24}a^{\mu_{11}}}{k_3^2} - 2\frac{a_{13}a^{\mu_{11}}/4 - a_{13}^{\mu_2}}{k_1k_2} + \frac{2\,a_{13}^{\mu_2} + a_{13}a_{24}^{\mu_{11}} - a_{13}a^{\mu_{11}}{}_{11}/2}{k_2k_3} - 2\frac{a_{13}a^{\mu_{11}}/4 + a_{24}a^{\mu_{11}}/4 - a^{\mu_2}/8 - a_{13}^{\mu_2} - a_{13}a_{24}^{\mu_{11}} + a_{13}a^{\mu_{11}}{}_1/2}{k_1k_3}. \quad (3)$$

To evaluate (3), we require the values of $a_{13}^{\mu_2}$, $a_{24}^{\mu_2}$, a^{μ_2}, $a_{13}a_{24}^{\mu_{11}}$, $a_{13}a^{\mu_{11}}$, and $a_{24}a^{\mu_{11}}$. Wishart (4), (5) has derived the general product-moment distribution for the case of a normally distributed population and any number of variates, and he gives a table of the moment coefficients of this distribution (4) and illustrates its use (5). Designating a product-moment coefficient in the sampled population, α, to correspond with the a from the sample, we have

$$a_{13}^{\mu_2} = \frac{N-1}{N^2}(\alpha_{11}\alpha_{33} + \alpha_{13}), \quad (4)$$

$$a_{24}^{\mu_2} = \frac{N-1}{N^2}(\alpha_{22}\alpha_{44} + \alpha_{24}), \quad (5)$$

$$a^{\mu_2} = \frac{N-1}{N^2}(\alpha_{(1+3)(1+3)}\alpha_{(2+4)(2+4)} + \alpha_{(1+3)(2+4)}), \quad (6)$$

$$a_{13}a_{24}^{\mu_{11}} = \frac{N-1}{N^2}(\alpha_{12}\alpha_{34} + \alpha_{14}\alpha_{23}).$$

Assume that

$$\alpha_{12} = \alpha_{14} = \alpha_{23} = \alpha_{34} = \alpha/4.$$

Then

$$a_{13}a_{24}^{\mu_{11}} = \frac{N-1}{N^2}(\alpha^2/8). \quad (7)$$

If this assumption does not hold exactly, $a_{13}a_{24}^{\mu_{11}}$ will be overestimated to the extent that the sums of squares $(\alpha_{12}^2 + \alpha_{34}^2)$ and $(\alpha_{14}^2 + {}_{23}^2)$ exceed the corresponding products $(\alpha_{12}\alpha_{34})$ and $(\alpha_{14}\alpha_{23})$. These differences should not ordinarily be large,

unless the product-moments vary quite considerably from one another, which is unlikely. Note that we may expect that $\alpha_{12}\alpha_{34} = \alpha_{14}\alpha_{23}$, i.e., that the tetrad equation should hold, as we are dealing entirely with a single function.

$$a_{13}a^{\mu_{11}} = \frac{\Sigma a_{13}a}{M} = \frac{\Sigma a_{13}(a_{12} + a_{14} + a_{23} + a_{34})}{M}$$

$$a_{13}a^{\mu_{11}} = a_{13}a_{12}{}^{\mu_{11}} + a_{13}a_{14}{}^{\mu_{11}} + a_{13}a_{23}{}^{\mu_{11}} + a_{13}a_{34}{}^{\mu_{11}},$$

$$a_{13}a_{12}{}^{\mu_{11}} = \frac{N-1}{N^2}(\alpha_{11}\alpha_{23} + \alpha_{12}\alpha_{13}),$$

$$a_{13}a\ {}^{\mu_{11}} = \frac{N-1}{N^2}(\alpha_{11}\alpha_{34} + \alpha_{14}\alpha_{13}),$$

$$a_{13}a_{23}{}^{\mu_{11}} = \frac{N-1}{N^2}(\alpha_{33}\alpha_{12} + \alpha_{23}\alpha_{13}),$$

$$a_{13}a_{34}{}^{\mu_{11}} = \frac{N-1}{N^2}(\alpha_{33}\alpha_{14} + \alpha_{34}\alpha_{13}),$$

Adding the last four equations,

$$a_{13}a^{\mu_{11}} = \frac{N-1}{N^2}(\alpha_{11}(\alpha_{23} + \alpha_{34}) + \alpha_{33}(\alpha_{12} + \alpha_{14}) + \alpha_{13}(\alpha_{12} + \alpha_{14} + \alpha_{23} + \alpha_{34})).$$

Assume that

$$\alpha_{23} + \alpha_{34} = \alpha_{12} + \alpha_{14} = \frac{\alpha}{2}.$$

Then

$$a_{13}a^{\mu_{11}} = \frac{N-1}{N^2}\left(\frac{\alpha}{2}(\alpha_{11} + \alpha_{33}) + \alpha_{13}\alpha\right). \tag{8}$$

If this assumption does not hold strictly, the value of $a_{13}a^{\mu_{11}}$ will be underestimated slightly. The amount of underestimation should seldom be large, particularly as it will only occur in case α_{11} is also markedly different from α_{33}, which, too, is unlikely, since these are both variances of comparable measurements.

By a similar line of reasoning,

$$a_{24}a^{\mu_{11}} = \frac{N-1}{N^2}\left(\frac{\alpha}{2}(\alpha_{22} + \alpha_{44}) + \alpha_{24}\alpha\right). \tag{9}$$

This completes the purely mathematical solution, as the values from (4), (5), (6), (7), (8) and (9) may be substituted in (3) to give the needed estimate. We must of course substitute the a's computed from the data for the α's of the formulæ.

For purposes of computation, it is well to lay out the necessary arithmetical steps in a job analysis. For this purpose it will be convenient to redefine some of the measures.

Let x be the total initial score, composed of the sum of the two parts x_1 and x_3, and let y be the total final score, composed of the sum of the two parts y_2 and y_4. Then from the data we should compute σ_x^2, σ_1^2, σ_3^2, σ_y^2, σ_2^2, σ_4^2, and $\sigma_{(x-y)}^2$. From these values, we have

$$a_{13} = \frac{\sigma_x^2 - \sigma_1^2 - \sigma_3^2}{2},$$

$$a_{24} = \frac{\sigma_y^2 - \sigma_2^2 - \sigma_4^2}{2},$$

$$a = \frac{\sigma_x^2 + \sigma_y^2 - \sigma_{(x-y)}^2}{2}.$$

From these basic values, we have

$$r_{xx} = \frac{a/4 - a_{13}}{\sqrt{a_{13}^2 + a_{13}a_{24} - a_{13}a/2}}. \tag{10}$$

We define

$$k_1 = a/4 - a_{13},$$

$$k_2 = 2a_{13},$$

$$k_3 = 2a_{13} + 2a_{24} - a,$$

$$n = \frac{N - 1}{N^2},$$

$$m_1 = n(\sigma_1^2\sigma_3^2 + a_{13}),$$

$$m_2 = n(\sigma_2^2\sigma_4^2 + a_{24}),$$

$$m_3 = \frac{n}{16}(\sigma_x^2\sigma_y^2 + a),$$

$$m_4 = na^2/8,$$

$$m_5 = \frac{n}{8}(a(\sigma_1^2 + \sigma_3^2) + 2a_{13}a),$$

$$m_6 = \frac{n}{8}(a(\sigma_2^2 + \sigma_4^2) + 2a_{24}a).$$

Then

$$\sigma_{r_{zz}} = \frac{1}{r_{zz}}\left(\frac{m_3 + m_1 - 2m_5}{k_1^2} + \frac{m_1}{k_2^2}\right.$$
$$\left. \frac{+ m_1 + m_2 + 4m_3 + 2m_4 - 4m_5 - 4m_6}{k_3^2} - 2\frac{m_5 - m_1}{k_1 k_2}\right.$$
$$\left. - 2\frac{3m_5 + m_6 - 2m_3 - m_1 - m_4}{k_1 k_3} + 2\frac{m_1 + m_4 - 2m_5}{k_2 k_3}\right)^{\frac{1}{2}}. \quad (11)$$

Finally

$$\text{P.E.}_{r_{zz}} = .6745\sigma_{r_{zz}}.$$

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THE EFFECT OF THE EXPOSURE TIME UPON THE R. L. OF VISIBLE MOTION

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The lower limit of visible motion has been determined by a number of investigators under different conditions. Porterfield [1] made the observation by fixating a moving object in an otherwise motionless but unrestricted field of vision. Some time later G. G. Schmidt,[2] Muncke,[3] and Valentin [4] made similar determinations upon the second hand of a watch. Aubert [5] brought the observation under more adequate experimental control by the use of lines on a rotating drum whose rate could be altered and measured accurately. He determined to some extent the effect of the surrounding field upon the limen. With an unrestricted field of stationary visible objects and with fixation on the moving object, Aubert's results agreed with those of the earlier investigators. When the visual field was restricted to the drum seen through an opening in an otherwise uniform black field, the limen was increased tenfold. The sides of the opening in the screen formed, of course, a stationary basis for spatial comparison with the moving stimulus. To eliminate all such bases of judgments, Aubert repeated his experiments with a point of light in a lightless field. Under these conditions the perception of motion became highly unstable. The observers perceived motion when the stimulus was stationary and contrariwise. The presence of a second stationary line in the dark field did not alter the results materially. Aubert concludes, therefore, that a stationary field of known objects is necessary as a background for the perception of motion. Bourdon [6]

[1] W. Porterfield, *Treatise on the eyes*, Edinburgh, 1759, 2, 416.

[2] G. G. Schmidt, *Handbh. u. Lehrbh. d. Naturlehre*, Giesen, 1825, 472.

[3] H. Muncke, "Gesicht" in Gehlers *Wöterbuch*, 1475.

[4] G. Valentin, *Lehrbuch d. Physiol.*, 1848, 2, pt. 2, 184.

[5] H. Aubert, *Pflügers Archiv*, 1886, 39, 347; 1887, 40, 459, 366.

[6] B. Bourdon, La perception visuell de L'espace, Paris, 1902, 178.

examined this latter perception and found that motion is perceptible in a totally restricted field, but that it requires a considerable amplitude.

Aubert determined further the limens of perceptible motion in the periphery of the field of vision, and found them to be much larger than for the fovea but smaller than the limens for spatial discreteness in the same regions. This seems to be the basis for the assertion which is current that the perphery of the retina is especially sensitive to movement. The difference limen, according to Aubert, is the same as the stimulus limen, *i.e.*, about one minute of arc. Bourdon, on the other hand, gives the relative D. L. as 1/8 to 1/12 for slow and medium rates respectively. Fleischl [7] and Aubert both showed that the limen is smaller when the eyes follow the moving stimulus than when they fixate a given point. Finally, Bourdon determined the maximum rate that appears as movement. Later investigators have worked on related problems, but their results have not altered materially the original limenal determinations.

Aubert appears to have taken some account of the effect of the time of exposure for he states that the minimum limenal value was obtained when the movement was viewed for several seconds. It is the more precise determination of the effect of this factor of exposure time at which the present investigation is directed.

Apparatus

The apparatus consisted of a black screen 67 x 84 cm with a moveable white dot 2 mm square at the center. This screen was set up in a dark room 240 cm from the *O*, at which distance the white dot subtended an angle of 2′ 42″. The face of the screen was illuminated by a 100 wt. daylight mazda lamp situated above *O*'s head and turned on only for the exposure periods. No light fell directly into *O*'s eyes and there were no shadows on the screen. *O* was seated in a straight-backed chair provided with a head rest to prevent head movement and one eye was covered.

[7] E. V. Fleischl, *Sitzungsber d. Wiener Akad.*, Math.-Naturw, Klasse, 1882, 86 (3).

The white dot was a square of Baryta white paper carried on an endless thread which ran horizontally across the front and back of the screen. The movement of the dot was produced by pulling in either direction on the thread which ran behind the screen. The rate of movement was controlled by means of a revolving drum graduated in cm. steps over which the thread passed. The exposure time was controlled by a contact driven from the drum.

Procedure

The limens for the perception of movement were determined by the method of constant stimuli for four lengths of exposure namely, ½ sec., 1 sec., 2 sec., and 4 sec. with three *O*s, D. P. Barrett (B), R. M. Sanders (S), T. C. Orr (O), seniors majoring in psychology and for the exposure time of 1 sec. with an additional *O*, Dr. Claire C. Dimmick (D).

At the beginning of each experimental period the *O*s were instructd as follows: "After a ready signal the screen will be exposed for ½ sec. (1 sec., 2 sec., and 4 sec.). You are to judge whether the white dot upon it moves and, if it does, in what direction it moves. You will be asked later to describe the criteria upon which you base your judgment."

TABLE I

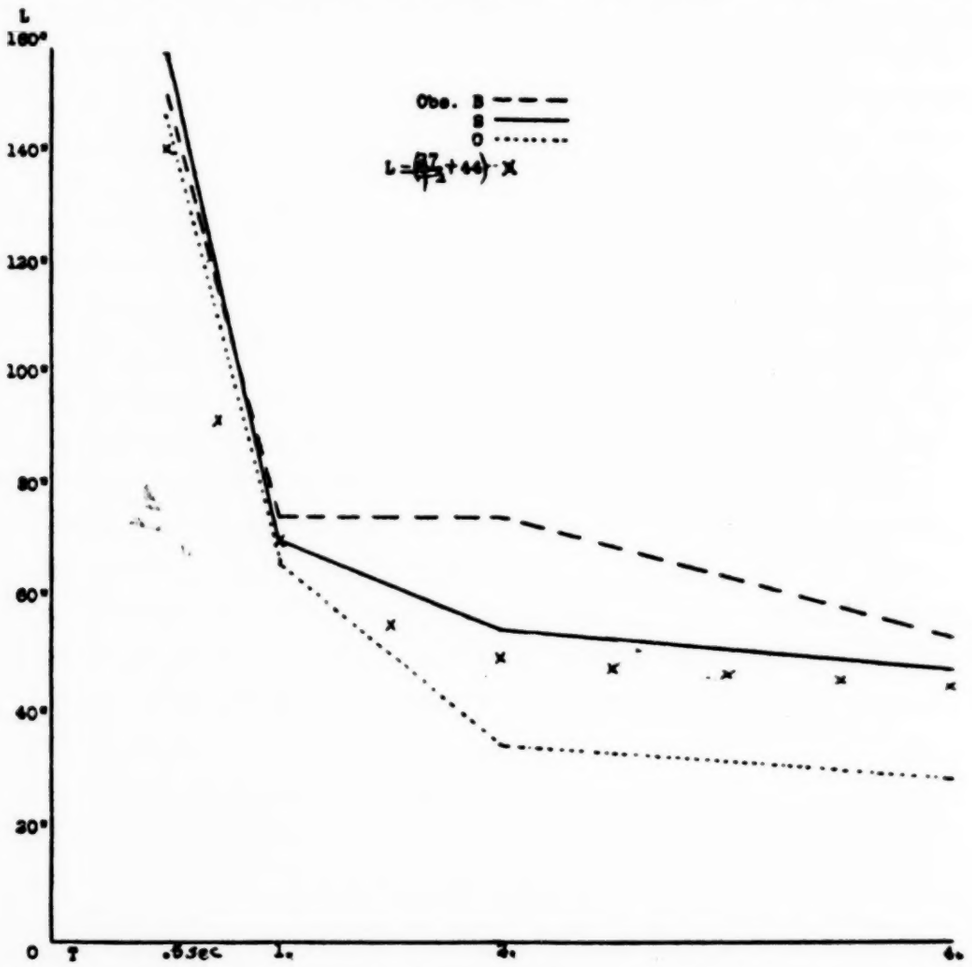
LIMENS IN SECOND OF ARC PER SECOND [8]

Time of exposure	½ sec.		1 sec.		2 sec.		4 sec.	
O	L	h	L	h	L	h	L	h
D	—	—	102.27	.011	—	—	—	—
B	151.14	.021	75.20	.021	75.05	.017	54.72	.020
S	159.72	.021	71.90	.018	55.31	.012	48.86	.020
O	148.63	.019	66.49	.018	34.79	.015	28.46	.020
Av.	153.16 mv.		71.79 mv.		53.38 mv.		44.01 mv.	
		4.37		2.81		5.69		10.37
$L = (27/I^2 + 44)$	152		71		50.75		45.7	

[8] The results presented certain difficulties for calculation. From the higher stimuli down to the region of the limen the P-values followed the usual course of the $\phi(\gamma)$ curve. Below the limenal region the curve flattened and sometimes actually rose. At the same time, the number of positive judgments that were in the wrong direction increased disproportionately. In the first calculation these judgments had been counted as minus. It seemed apparent that they were based upon guesses whose probable correctness would be 50 per cent. Therefore we determined the percentage (Pg) of wrong guesses for every stimulus and subtracted them from the total percentage of plus judgments (Pt) and made our calculations from the corrected percentages (Pc), (Pt − Pg) = Pc, the Pc values gave consistent $\phi(\gamma)$ curves.

I am indebted to Professor W. P. Durfee for the mathematical expression of the curve.

The several limens for the various *O*s are shown in Table I and their graphical relations in Fig. 1. The most striking feature is that the limen decreases at first very rapidly and then more slowly as the exposure time is lengthened from ½ sec. to 4 sec. The just perceptible movement may be said



said then to be inversely dependent upon the exposure time. The shape of the curve indicates, however, that this is not the only factor involved. In Table II we have compiled from the average limens of Table I the distance through which the moving point must travel at the given rates in order for it to be perceived as moving.

TABLE II

Rate	Exposure Time	Arc Traversed
153.76	½	76.58″
71.19	1	71.19″
55.38	2	106.76″
44.01	4	174.04″

With the very short intervals this distance remains relatively constant at a magnitude only slightly larger than the minimal visible magnitude. With 2 and 4 sec. intervals and their respectively slower minimal rates a much larger angular movement is necessary. It is evident that the bases of judgment must be different in the two cases. When the exposure time is one second or less the stimulus must move at such a rate that its initial and final positions will be separated by a distance just greater than the spatial limen. Under these conditions the perception simulated the simultaneous presentation of two points. The longer times made possible the judgment of movement when this simulation was not realized but such judgments required larger separations of the two positions. They are related, probably, to the spatial limen for sucessive stimuli. It is possible that they may have required orientation marks though we were unable to discover any. All of the judgments were immediate and appear to be based upon simple integrations of extents. Duration was present simply as the factor in the stimulus which modified these extents. We made no attempt to determine what implicit factors such as eye movement might be involved.

Summary

The lower limen for the perception of visible motion, measured in sec. of arc per sec., decreases as the exposure time increases. For the shorter exposures, the values are almost identical with that of the minimal space limen. With the longer exposure times the spatial values of the limens increase. The perceptions appear to be simple integrations of extents, in the first case simultaneous in the second case successive. Duration enters simply as the stimulus factor that modifies these extents.

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THE RELATIONSHIP OF "INTELLIGENCE" AND REFLEX CONDUCTION RATE AS FOUND IN HYPOPHRENIC CHILDREN [1]

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Two studies have already been made regarding the relationship of reflex time and intelligence. The first of these studies (1) reported a high correlation existing between the two. The second study (2) reported no demonstrable correlation between the two. Endeavoring to adduce further information to determine any such relationship a third study—the subject of this paper—was undertaken.

Particular care was had to obtain a group of subjects who represented a distinct departure from the group type of the second study in that its every constituent occupied an unquestionably low intellectual order, the upper limit of its intellectual range stopping at the mid-imbecile level.

An attempt was made to obtain as pure as possible a culture of what might be regarded as native hypophrenia—individuals defective uniformly by virtue of fore-shortened ontogeny, *i.e.*, developmental arrest rather than acquired defect. Thus the familiar stocks laden with instances of hypophrenia, the relative absence of acquired causes which might account for the intellectual inferiorities, the high incidence of conspicuously inferior social statuses were all valuable determinants in the choosing of suitable cases for our study. Individuals were further seeded so that whenever demon-

[1] Permission was obtained from Dr. George Mogridge, Superintendent of the Iowa institution for the Feebleminded at Glenwood, Iowa, through Dean C. E. Seashore of Iowa University to establish our laboratory in that institution. We wish to thank Dr. Mogridge and his staff for their ready cooperation with us in this project.

strable hypoplastic types were favored—a type of physical stigmatization indicative of a general undifferentiation being sought for. Individuals presenting other syndromic characteristics or essential neurological or somatic deviations were ruled out as undesirable subjects.

A supplementary study of a series of Mongolian types was also made. This group likewise included only high and low grade idiots, and low and mid-grade imbeciles. Here as in the main study similar care in selection of subjects was exercised.

As in the two foregoing works we determined the reflex time with the action current technique (1) (2).

Since standing height even more than length of the peripheral arc correlates higher with reflex time (both patellar and Achilles tendon determinations) than does any other single physical measurement (2) the ratio, height divided by time, was chosen as a unit for group comparisons.

In the presentation of data we have arranged the subjects into the following five groups: (1) hypophrenic proper, including all of the cases with the exception of the Mongol series; (2) Mongol, including the special series of subjects of the relatively more uniform physical stigmatization; (3) total hypophrenic, including all of the cases in groups (1) and (2) with ages ranging from 4 to 14 years; (4) hypophrenic and Mongol, including all cases with ages ranging from 7 to 10 years; and (5) superior, including children with a mean I. Q. of 118.56 of ages ranging from 7 to 10 years.[2]

TABLE 1

GROUP COMPARISONS

Group	Mean Reflex Time	Range Reflex Time	Height Time	Number of Cases
Hypophrenic	15.4	13.0–18.3	8.3	42
Special Mongol	14.8	11.1–17.0	8.5	15
Total Hypophrenic	15.3	11.1–18.3	8.5	57
Hypophrenic and Mongol, ages 7 to 10 years.	14.8	11.1–18.0	8.4	29
Superior, ages 7 to 10 years.	15.3	12.9–16.6	8.5	47

The above results demonstrate no significant differences

[2] This last group is taken from the second report already mentioned.

between the reflex time of any of the hypophrenic groups and that of the superior group.[3]

The present paper supports the findings of the second report in that it discovers no relationship between intelligence and patellar tendon reflex time. In the light of these more recent findings the distinguishable difference in reflex time of the first report then accounted for on the basis of intellectual differences is now felt to be best accounted for on the basis of either an accidental frequency distribution of unrecognized extraneous factors, or the unreliability of the phoneloscopic procedure.

Although there may be a relationship between reflex time and intelligence, since it is so readily conceivable that extremely small differences in the former might represent extremely significant differences in the latter, such a relationship is not demonstrable within the reliability of this present work's technique.

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[3] The second report likewise demonstrated that the ratio height over time varied in no significant degree between groups ranging from pre-school to University years.

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